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APPLIED MECHANICS REVIEWS

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NONLINEAR OSCILLATIONS

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1. INTRODUCTORY REMARKS

TWO earlier feature articles in this journal (1) (2) dealt with the problem at hand. In the first article only a brief paragraph was devoted to the subject. The second one dealt primarily with four particular phenomena as examples of fields in which future work may be expected; no literature was quoted.

In contrast, this present article aims at providing a guide to the literature, in particular to sources describing more recent achievements. Most of the earlier literature will be referred to by way of textbooks and former survey articles. This fact should be kept well in mind when items are found missing from the list of references.

Understandably, it will be impossible to aim at completeness, let alone achieve it. Nor would such an aim be a desirable one. Only the more significant literature will be mentioned, and only such publications will be listed in regard to which some pertinent statement can be made, either in regard to their contents or to their places in the evolutionary process. Inevitably, this selection will be strongly influenced by the author's views, opinions, and, maybe, prejudices.

Furthermore, the author is beset with one grave difficulty right from the start: his nearly complete lack of ability to read the original Russian literature. This is a severe handicap for one who sets out to report on a field where very much authoritative work has been done by Russian researchers. Work of Russian writers will be mentioned by recourse to cumulative sources (like textbooks) or to survey and report articles in one of the "western" languages. The author's feeling of incompetence in this respect is alleviated to some extent by the realization that the majority of readers of this article will also have to take refuge in interpretations of the Russian literature in one of the western languages, and, hence, will still be served adequately.

2. NONLINEAR DIFFERENTIAL EQUATIONS

The physical topic of nonlinear oscillations is intimately related to the mathematical topic of nonlinear differential equations. Advances in one field depend upon, and in turn produce, advances in the other. Therefore, we shall start with a short survey of the literature on nonlinear differential equations.

The most important recent event in this area is the appearance of the book by Coddington and Levinson (3). It represents a competent and modern account on the subject with carefully chosen references. In addition to this work, three more items merit mention: the book by Lefschetz (4), the three volumes (5) edited by Lefschetz, and the report by R. Bellman (6). The references in these publications should be sufficient to provide guidance to further sources. A special guide to the Russian literature on differential equations is given by an article by S. Lefschetz (7).

3. SURVEYS AND COLLECTIVE PUBLICATIONS

In regard to the history of the subject and to the cumulative literature up to 1954, the author wishes to be brief by referring primarily to his own survey article (8) which contains a bibliography of more than ninety items and where particular attention has been given to the historical aspects and also to former surveying articles. However, three more items should be added to the bibliography of (8): two earlier general surveys, one by Minorsky (9), another by Miss Cartwright (10), and finally, an article by Bellin (11) in which the mathematical advances are reviewed in regard to differential equations containing the time explicitly.

Two survey articles mentioned in (8) are listed here again (12) (13); they should be consulted for literature before 1940. In addition, a few "landmarks" may merit repeated mention. The report by Minorsky (14), published in 1947, summed up most of the earlier theoretical work, with particular attention to Russian sources; it sparked renewed activities in the western world. About the same time two edited translations of Russian monographs (15) (16) helped this development. In 1950, two textbooks on the subject appeared (17) (18). A later book (19) is of the monograph type again.

More recently, Clauser (20) gave a lively written account of nonlinear oscillatory phenomena. Some items in that paper, mostly in regard to nomenclature, were commented upon by the present author (21). Recent Russian achievements were surveyed by K. Magnus (22). Further articles based (at least in part) on Russian work will be mentioned later in specific context; they are (45) (46) (63) (64) (67).

The list of collective publications may be headed by two conference reports (23) (24). A field where nonlinear oscillatory phenomena play an increasingly important role is control engineering. The literature on controls abounds with papers pertaining to our subject. The present article can take notice of them only to a limited extent. Collective publications on controls mostly result from meetings or conferences. In the meetings on controls organized in 1953 and 1956 by ASME, the nonlinear features received some attention and coverage. The papers of the 1953 meeting appeared jointly in (25) and subsequently were published in book form (26); those of the 1956 meeting appeared in (27).

Two symposia, organized in 1953 and 1956 by the Microwave Research Institute of the Polytechnic Institute of Brooklyn, dealt with nonlinear circuit analysis. The Proceedings (28) (29) of both meetings contain many papers of

basic importance in regard to nonlinear oscillation theory, as well as some very valuable survey articles. Examples: 1953: E. Weber, Nonlinear physical phenomena; K. O. Friedrichs, Fundamentals of Poincare's theory; S. Lefschetz, Russian contributions to differential equations; 1956: W. Kaplan, Stability theory; and many others. A most important event was the conference on control engineering held at Heidelberg, Germany, in September 1956 and attended by researchers from all over the world. Publication of the proceedings is pending (30).

4. NONPHYSICAL FIELDS

The interest in and the study of nonlinear oscillation phenomena have spread beyond the realm of physics and engineering, particularly into biology and economics. The *Bulletin of Mathematical Biophysics*, for instance, contains numerous papers dealing with nonlinear phenomena, mostly in biochemical processes. The journal *Econometrica* abounds with articles on oscillation phenomena in economics. Although most of the articles are descriptive in essence, some of them aspire at finding the "dynamical mechanisms."

Two biological phenomena are receiving particular attention: (1) cycles in animal population; (2) the so-called "Biological clocks." In regard to literature on the first item, it may suffice to mention the true classic (31). The second phenomenon is an extremely interesting one. At present, biologists strive to describe and to understand the observed facts in terms of nonlinear oscillation theory. Recent and representative accounts on this fascinating subject are (32) (33) (34).

In regard to economical systems, it may suffice to refer to Tustin's monograph (35). The Proceedings of the Cranfield Conference (24), mentioned above, also contain some references to economic systems.

In Germany recently, two conferences were held dealing with the control aspects of biological and of economic systems respectively. The papers presented were published collectively (36). The objects of study in nearly all cases are basically nonlinear oscillation phenomena.

5. SPECIAL SYSTEMS; EXACT SOLUTIONS

The majority of nonlinear differential equations do not admit of closed form or exact solutions. Most of those which do are listed in Kamke's "Catalogue" (37). A short review of those nonlinear oscillation phenomena which lead to closed form solutions is found in (8).

Recently, by making use of the identity $\ddot{x} = d(\dot{x}^2/2)/dx$, the present author and his associates transformed two types of nonlinear differential equations (quadratic damping; "modified van der Pol's differential equation") to piecewise linear ones which can be treated rather readily (38) (39).

Among the many possibilities of transforming a differential equation (with the aim of producing forms which are easier to handle) there is one which consists of simply inverting the roles of the dependent and independent variables. Such a process requires the knowledge of $d^n y/dx^n$ in terms of $d^k x/dy^k (k = 1 \ldots . n)$. The pertinent formulas have been listed in a report by McAllister and Thorne (40).

6. METHODS FOR FINDING APPROXIMATE SOLUTIONS

a. *The classical methods.* Among the methods for finding approximate solutions, three may be called the "classical" methods: (a) perturbation, (b) iteration, (c) series reversion. In regard to the literature on topics (a) and (b), the foremost reference is (3). The field of the so-called "singular perturbation" has been covered in a number of papers by Wasow of which (41) may be representative ones. Furthermore, the paper by Carrier (42) merits mention in this connection. The difficulties which arise from singularities being present in the "zero-order solution" have led to extensions of the original Poincaré procedure. A good account of those developments has been given by Tsien (43). In regard to both (b) and (c), reference is made to (8); to the papers listed there, item (44) should be added.

b. *"Averaging" methods.* Under this heading two methods will be discussed, which have proved to be extremely useful tools and, therefore, have found wide application. The two methods will be identified as (a) "The method of equivalent linearization" and (b) The Ritz-Galerkin method.

The method of "equivalent linearization" originated with the Russian authors Kryloff and Bogoliuboff. Of their book on the subject (1937), an English version has been edited by Lefschetz (16). Due to this accessible source, the method has also received wide attention outside Russia among physicists and engineers; by mathematicians, however, it is occasionally frowned upon. Other workers of the Russian school elaborated on the method. In particular, the method has been extended to equations of order higher than two. An account of its more recent versions has been given by K. Magnus (45) (46). In these investigations the method, furthermore, has been linked to the stability criterion of Hurwitz. Subsequently, the same writer extended the method to include systems involving time delay (48). A paper by Bass (49) deals with both the mathematical and the engineering aspects of equivalent linearization; this paper, furthermore, is well documented.

In regard to (b), it may be mentioned that the present author in 1951 drew attention to the usefulness of the well-known Ritz or Ritz-Galerkin procedure for the purpose of solving (autonomous and nonautonomous) nonlinear differential equations having periodic solutions (50). In 1956, he furthermore showed (52) (53) (54) how, on the basis of this method, the concept of the "describing function" [introduced in 1950 by Kochenburger (51)] can be extended to include elements whose behavior is represented by a nonlinear differential equation, as contrasted to a nonlinear algebraic equation.

The Ritz method was used also to deal with superharmonics and subharmonics (55) and with systems of more than one degree of freedom (56) (57). A very recent dissertation (58) finally extends the range of the Ritz method to approximating functions which do not have the conventional form of a product between an (open) coefficient and a (predetermined) coordinate function (or a sum of such products) but which are of a more general type; as, for instance (A and α being the parameters),

$$x = \frac{A}{\alpha - 1}(\alpha r - r^{\alpha})$$

and, hence, provide a more flexible instrument.

c. *Methods associated with the concepts of phase plane or amplitude plane.* In regard to this topic, the author again wishes to refer primarily to his report (8). Not much need be added to that account and to the references given there, except perhaps to mention that Ku reported further on his work in a number of papers [e.g., (59)] and that the concepts of the phase plane has been used also in the study of control problems [representative example (60)].

7. SPECIAL TYPE PROBLEMS

Among the special types of problems which received major attention are the following:

(a) Forced oscillations in systems capable of auto-oscillations.
(b) Stability of nonlinear oscillations.
(c) Discontinuously operating systems.

Problem (a) is an important one for "active" electrical circuits. Mechanical counterparts, though existing and known, do not play an equally important role. Therefore, here it will suffice to mention the extensive work of Cartwright and Littlewood. A representative account of this work has been

given by Miss Cartwright herself (61); other references are Bellin's report (11), Stoker's book (17), pp. 147–187, and Minorsky's survey article (2).

Problem (b), the stability of nonlinear oscillations, has been approached in two basically different ways. The first way, in turn, has two branches. One consists of the method of "equivalent linearization" and its linkage to the Hurwitz criterion [see e.g., (45) (46) (48)]. The second branch is represented by the "describing function" technique [see e.g., (52) (54)]. Although the two branches are methodically somewhat different, they run within the same territory, making use of the same basic concept: linear equivalence or sinusoidal equivalence.

The second approach to the stability problem is radically different, however. There one refrains from borrowing "linearized" ideas, and one deals with the nonlinear problem directly. The guiding principles of this approach are laid down in the classical work of Liapunov (62). For half a century Liapunov's ideas were considered a rather lofty theory. In recent years Liapunov's fellow countrymen set out to work the theory like a gold mine for practical yields. And they found their efforts well rewarded. Brief, even sketchy, but readable "western" accounts on the use of "Liapunov's method" are found in the papers by Hahn (63) and Pestel (64). The survey paper by Kaplan in (29) deserves repeated mention at this point.

(c) Discontinuously operating systems are intrinsically nonlinear. They are of high practical interest in control engineering. As representative accounts we mention the publication by I. Flügge-Lotz (65) and extensions of this work (66); furthermore, numerous papers in (28) and (29), notably that by McDonald (and his related papers), as well as in (25) (26) (27) and (30). The paper by T. F. Higgins in (27) contains an extensive bibliography. Finally, the paper by Haacke (67) ties in with Russian work on the subject.

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Theoretical and Experimental Methods

(See also Revs. 3533, 3540, 3541, 3546, 3561, 3562, 3587, 3616, 3635, 3651, 3652, 3668, 3683, 3697, 3700, 3725, 3776, 3782, 3791, 3794, 3795, 3822, 3874)

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Author investigates the n-th order differential equation applicable in automatic control theory

$$\frac{d^n x}{dr^n} + a_1 \frac{d^{n-1} x}{dr^{n-1}} + \ldots + a_{n-1} \frac{dx}{dr} + a_n(r)\, x = 0$$

where $a_1, \ldots a_{n-1}$ are positive constants and $a_n(r)$ a continuous periodic function of time r. It is essential that $a_n(r)$ has zeros. Application of Lyapunov's method leads to sufficient conditions of stability in the sense of Lyapunov for the trivial solution of the equation when $n = 3$ and 4.

J. Beranek, Czechoslovakia

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Paper is a mathematical study of an inconsistency which is noted between the theory and the practice of estimating truncation errors in numerical solutions to plane Dirichlet problems. Such estimations utilize the magnitudes of the partial derivatives of the exact solution to the problem, a practice which tacitly assumes these to be finite throughout the region of solution. In principle, however, the opposite is generally true when the boundary or boundary function is polygonal, as, in fact, they always are in finite difference approximations to the problem.

Paper establishes a set of necessary conditions which insure the truncation error to decrease uniformly with, and at least as rapidly as, the mesh size of the difference grid. Roughly speaking, this set requires analyticity of the boundary curve but allows certain singularities in the given boundary function. If the latter exist, it further requires the grid as well as the approximate boundary function to avoid the singularities, the strict sense of the term "avoid" being defined in the paper.

R. Drenick, USA

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Usual procedure for deriving numerical differentiation formulas for data given at equally spaced points is to construct the Lagrangian interpolation polynomial through the points, differentiate the polynomial, and evaluate at the points. Let (x_i, y_i), $i = 0, 1 \ldots n$, be the points and h the spacing. Paper develops formulas of the form $(d^k y/dx^k)_{y=y_i} = h^{-k} \sum_{j=0}^{n} A_{ij}^{k,s}\, y_j + 0(h^s)$, without constructing the Lagrangian. Usually $n + 1 = k + s$, but this need not be so.

Y. L. Luke, USA

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The usual procedure for solving a partial differential equation (p.d.e.) is to employ its finite difference analog. Generally, by employing difference quotients of sufficiently high order, one can reduce the truncation error. However, use of high-order differences introduces spurious solutions, and the system stability may be adversely affected. Paper illustrates a technique to reduce error in the difference equation without introducing differences of higher order than found in the p.d.e. A numerical example is provided.

Y. L. Luke, USA

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Y. L. Luke, USA

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The magnitude and direction of the resultant of a set of vectors in a plane may be determined or checked by merely locating the centroid of the starting points of the vectors, and joining this to the centroid of their end points. This graphical method provides a basic procedure in the application of vector analysis to physics problems. E. G. Fischer, USA

3522. Elliott, D. A., Representation of nonlinear functions of two input variables on analog equipment, *Trans. ASME* **79**, 3, 489–495, Apr. 1957.

A method for generating nonlinear functions of two variables economically using standard analog equipment is presented. The technique involves the breakdown by graphical means of the original function of two variables into a combination of functions of each of the variables taken individually. This technique is limited to families of curves of such nature that one member of the family can be forced to match all other members simply by rotation and/or translation. Superimposing these curves must be done by trial and error and may be time consuming.

M. L. Baker, USA

3523. Gorup, G. v., Formula and tables of an integral related to Hankel's cylindrical function (in German), *Mitt. Max-Planck-Inst. Strömungsforschung no.* 15, 58 pp., 1957.

Author studies the function $T_n(z) = \int_0^\infty e^{-nt}\, e^{-z\cosh t}\, dt$ and develops various expansions for its numerical evaluation. $S_n(z) = e^z T_n(z) = e^z K_n(z) - R_n(z)$, where K_n is the modified Bessel function and R_n is a polynomial of degree n. Let $S_n(iz) = \alpha_n(z) - i\beta_n(z)$. For $z = -ik$, 9d tables of the real and imaginary parts of T_n, α_n, β_n and $1/n - \alpha_n$ are given for $n = 1(1)40$, $k = 0.001$, 0.002, 0.005, 0.01(0.01)0.1(0.1)2(1)7. The above integral arises in an aerodynamic problem concerning wing vibration, and integrals of above type also occur in researches on diffraction of a prism. Author seems unaware of some previous studies of $T_n(z)$ and related integrals. In this connection, see Watson, G. N., "A treatise on the theory of Bessel functions," Cambridge, 1945, p. 313, and Luke, Y. L., "An associated Bessel function," *J. Math. Phys.* **31**, 131–138, July 1952. Y. L. Luke, USA

3524. Prager, W., Numerical solution of the generalized transportation problem, *Brown Univ., Div. appl. Math.* IBM-18, 20 pp. Nov. 1956.

Paper presents an example of numerical solution of generalized transportation problem; the uniqueness of solution and extremum properties were established in a previous paper [AMR **10**, Rev. 1660].

The "typical" problem is as follows: the rate of production (or consumption) is given at each plant (or market); the total rate of production of which the plants are capable does not equal the rate at which the markets can absorb the product, and a financial penalty is assessed at each market for the unit rate of unsatisfied demand.

The method, which is an extension of that of Ford and Fulkerson [Rand Corporation, Pap. P7439, Sept. 1955; see also Rand Corporation, Pap. P-895, June 1956], consists of repeated applications of two basic stages: (1) "Saturating given routes, and (2) raising prices. Step 1 raises the rates of consumption by using available routes under the price system of the problem modified by adding a store and dump, each characterized by zero price. Step 2 brings new routes into play by raising prices so that routes already in use are not eliminated.

The method is relatively simple after one has read and re-read ... the paper. E. Koenigsberg, USA

3525. Azpeitia, A. G., On the method of leading variables in linear programming, *Brown Univ., Div. appl. Math.* IBM-17, 9 pp., July 1956.

Author obtains results which make it possible to avoid useless computations which may occur in using the method of leading variables to solve a linear program. Two theorems are proved which provide necessary and sufficient conditions for a nonleading variable at one stage of the computation to remain so at the next. A third theorem establishes conditions under which a variable can not be the principal variable at any stage of the computation.

M. Shubik, USA

3526. Rohde, F. Virginia, Bibliography on linear programming, *Operat. Res.* **5**, 1, 45–62, Feb. 1957.

3527. Diederich, F. W., Expected number of maxima and minima of a stationary random process with non-Gaussian frequency distribution, *NACA TN* 3960, 21 pp., Apr. 1957.

A method is outlined for calculating the expected number of maxima or minima of a random process with non-Gaussian frequency distribution from the statistical moments of the process and its first two derivatives. This method is based on an estimate of the joint frequency function of the process and its first two derivatives given by means of a generalized form of Edgeworth's series; the procedure thus consists essentially in applying a correction to the results for a Gaussian process. The functions required in this procedure are calculated for the first two correction terms; therefore, the effects of skewness and kurtosis can be calculated, provided the required moments are known. Expressions are given for these moments in terms of multiple correlation functions and multi-spectra, and the relations between these functions for a random output of a linear system and those for the random input are indicated. From author's summary by H. D. Block, USA

Book—3528. Pantazi, A., The life and works of Alexander Pantazi [Opera Matematica a lui Alexandru Pantazi], Rumania, Editura, Academia Republicii Populare Romane, 1956, 494 pp. Lei 24.20.

Book—3529. Slaby, S. M., Descriptive geometry, (College Outline Series #101) New York, Barnes & Noble, Inc., xiii + 353 pp. $2.25.

Book—3530. Callaham, L. I., Russian-English technical and chemical dictionary, New York, John Wiley & Sons, Inc., xvii + 794 pp., 1956. $16.50.

Mechanics (Dynamics, Statics, Kinematics)

(See also Revs. 3593, 3846, 3847, 3848, 3850)

Book—3531. Dugas, R., A history of mechanics, New York, Central Book Company, Inc., 1955, 671 pp. $15.00.

This book, originally published in French in 1950, has been translated into English by J. R. Maddox. It covers the development of classical statics and dynamics, and the generalization of these into relativity theory and quantum and wave mechanics. Mechanics of materials and engineering applications are outside the scope of the work; celestial mechanics and hydrodynamics are touched on, as well as theory of light, where necessary to understand the development of the primary subject.

Chronological order is used, the book being divided into five main sections. Part I deals with origins and precursors from Aristotle to Kepler; part II, with the formation of classical mechanics from Stevin to Newton, Leibniz, and Varignon; part III, with the organization and development of mechanics in the 18th century, from the Bernoullis to Lagrange; part IV, with selected topics in post-Lagrangian classical mechanics, including Coriolis'

principles, and some interesting 19th century criticisms of Newtonian mechanics; and part V, with modern physical theories of mechanics up to about 1930.

Author makes use of extensive quotations from the original papers, and assumes (especially in part V) that the reader has a sound knowledge of higher mathematics and classical mechanics. It seems safe to say that he has written the definitive history in its field. Beyond this, reviewer refers the reader to his previous review [AMR **5**, Rev. 1605], and confines his further remarks to what is new in the English edition.

The translation is faithful to the original, and the occasional liberties with sentence structure are for the most part justifiable. Reviewer noticed only three or four really poor translations. On p. 95, the title "The Italian School of Nicholas Tartaglia and Bernardino Baldi" should read "... from ... Tartaglia to ... Baldi." On p. 123, "... Stevin eschewed the point of view of virtual velocities in order to romp in the field of pure statics" might better read "... in order to confine himself to the field..." The translation on p. 125 of Stevin's "*Wonder en is gheen wonder*" as "The magic is not magical" seems inferior to George Sarton's "The wonder is no wonder" ["Six wings" Bloomington, Ind., Indiana University Press, 1957, p. 80]. (Incidentally, Sarton's interpretation of the motto's meaning differs somewhat from that of Dugas.)

The author has taken advantage of the English edition to make some minor revisions and additions. About ten pages have been added to the end of the book, devoted to two notes; one on the mechanics of the Middle Ages, and one on the contributions of Poincaré to mechanics and relativity theory. We may also note a parenthetical insert crediting Archimedes with a definition of center of gravity. In the first edition, some axioms of Archimedes concerning centroids had been given, but the only previous mention of centroids had been that Aristotle was ignorant of them. Archimedes' definition was, however, lost, and the oldest recorded definition is that of Pappus (4th century A.D.)

There are a few insignificant misprints, but the publishers are to be congratulated for making accessible to the English-speaking world this important work in a fine translation and a handsome binding.

A. D. Topping, USA

Book—3532. Nekrasov, A. I., Textbook on theoretical mechanics [Kurs teoreticheskoi mekaniki], Moscow, Gostekhizdat, Vol. I, 5th ed., 388 pp., 1953; Vol. II, 2nd ed., 503 pp., 1953.

This is a standard textbook for Russian colleges and universities. Volume 1 covers statics and kinematics; volume 2—dynamics. Content of the texts can be seen from the headings of the chapters. Statics: force as a vector; moment of force and vector product; links and reactions, scalar product; concurrent forces; parallel forces; center of gravity; equilibrium of parallel forces; couple; coplanar force system; general force system; particular cases. Graphic statics: string polygon; some applications; girders.

Kinematics: velocity of a particle; acceleration of a particle; translation of rigid body and rotation of a rigid body about a fixed axis; plane motion of a rigid body; rotation of a rigid body about a fixed point; addition of angular velocities; simplification of a system of angular and linear velocities; general motion of a free rigid body; velocity and acceleration of a particle in a complex motion; moving coordinates.

Dynamics: work and power; principle of virtual displacements. Dynamics of a particle: Newton laws and problems of dynamics; integration of differential equations of motion of a particle; free translation of a particle; free translation of a particle due to the gravity; linear vibration of a particle; free motion of a particle in the plane and in the space; constrained motion of a particle; relative equilibrium and relative motion; Lagrange equations. Dynamics of a system of particles: differential equations of motion of a system and their integration; moments of inertia; rotation of a rigid body about a fixed axis; plane motion; equations of motion of a rigid body about a fixed point; Euler problem; Lagrange problem; D'Alembert principle and Lagrange equations; small oscillations of a system of particles about equilibrium position; impact.

Few examples are discussed at the end of each chapter. There are no problems for students and no references. The texts are written in an extensive and elaborate manner and in vector notation.

S. Kolupaila and L. H. N. Lee, USA

3533. Doolin, B. F., The application of matrix methods to coordinate transformations occurring in systems studies involving large motions of aircraft, *NACA TN* 3968, 36 pp., May 1957.

The present paper attempts to show how convenient it is to use rotation matrices when setting up the geometric aspects of dynamical problems. A rudimentary knowledge of certain aspects of matrix algebra provides a tool entirely adequate for the solution of these geometric problems. The compact notation of matrix algebra permits the clear view required for their straightforward solution. The detailed computation of the expressions required in a particular problem becomes a matter of routine, and can easily be checked for errors. No algebraic dexterity is required to determine the parameters involved because they are obtained by the same direct methods used in the rest of the problem. Many of the parts used in one problem can be saved and used in other problems. Finally, because planning and computing become distinct tasks, it is a simple matter for one to devise and investigate various paths to the solution of the geometric problems without performing any computations.

From the author's summary by Marvin Shinbrot, USA

3534. Rumiantsev, V. V., Stability of permanent rotations of a heavy solid (in Russian), *Prikl. Mat. Mekh.* **20**, 1, 51–66, Jan./Feb. 1956.

The permanent rotation of a heavy solid about a fixed point was treated first by Staude (in 1894). Using the inverse method, Grammel derived the stability criteria of Staude's motion [*Math. Z.* **6**, 1920]. In 1945, Bottema applied this method to the case when the center of gravity is in one principal inertia plane. Using Tchetaev's method for determing Liapunov's stability function, present author derives directly the approximate stability conditions of this motion in general and several special cases. The analysis of these conditions shows the possibility of determining the stability zone on the cone of permanent axes.

These cases are treated: (1). When the center of gravity is in the principal inertia plane ($x_0 > 0$, $y_0 > 0$, $z_0 = 0$; $A > B > C$ or $B > C > A$); (2). when the center of gravity lies on the principal inertia axis ($x_0 > 0$, $y_0 = 0$, $z_0 = 0$; $A > B > C$, $B > C > A$, $C > A \geqslant B$); (3). when special ratios exist between the inertia moments (the problems of: S. Kowalevski, $B = C = 2A$; Bobilev-Steklov, $A = 2B$; Steklov, $B > A > 2C$; Goriatchev, $AC = 8(B - C)(A - 2B)$, with $C > A > B$, $2B > A$ and $C > B > A$; N. Kowalevski, $AC = 9(B - C)(A - 2B)$; Tchapligin, $0.6 > CA^{-1}$ 0.5965, $1.5 < BA^{-1} < 1.5965$; and Goriatchev-Tchapligin, $B = C = 4A$).

D. Raskovic, Yugoslavia

3535. Slezinger, I. N., Motion of one of the simplest mechanical systems subjected to elastic forces and nonlinear friction, *Zh. tekh. Fiz.* **24**, 9, 1660–1676, Sept. 1954.

3536. Roberson, R. E., and Tatistcheff, D., The potential energy of a small rigid body in the gravitational field of an oblate spheroid, *J. Franklin Inst.* **262**, 3, 209–214, Sept. 1956.

3537. Kunin, N. F., and Lomakin, G. D., Relation between static and kinetic friction, (in Russian) *Zh. tekh. Fiz.* **24**, 8, 1367–1370, Aug. 1954.

3538. Meyer zur Capellen, W., Extreme velocities in crank mechanism linkages (in German), *Ing.-Arch.* **25**, 2, 140–154, 1957.

Four-bar linkages are of two types, depending on whether the driven link can make complete revolutions or can only oscillate.

In both cases, if the driving link rotates uniformly, the velocity of the driven link will have maximum and minimum values. This paper develops methods of determining the positions at which these occur. A review is given of the properties of Bress' circles and the Kardan-position. It is then shown that the Kardan-position is a required aspect of the linkage and a simple construction is given for locating this position, which method is simpler than methods based on determining zero tangential acceleration positions. The same analysis is also applied to determining the positions of maximum and minimum angular velocities of the connecting rod. Illustrations of the method are given for the general and several special cases, including various inversions of the slider-crank.

This is an intensive analysis of linkage properties. However, unless one is engaged in the constant application of such methods, he will probably continue to solve such problems by approximation methods. C. E. Balleisen, USA

3539. Sweeney, J. C., Gearbox layout—logarithmic spiral, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-1580, 7 pp.

Servomechanisms, Governors, Gyroscopics

(See also Rev. 3688)

3540. Flugge-Lotz, I., and Taylor, C. F., Investigation of a nonlinear control system, *NACA TN* 3826, 92 pp., Apr. 1957.

Control system consists of linear second-order elements to which have been added several discrete combinations of proportional and derivative feedback. Particular combination which is switched into the system is made to depend on combinations of signs of output, error, and their derivatives. System is thus piecewise linear but over-all nonlinear. Feedback values for particular system have been assigned by an experimental investigation using simulation techniques. It is indicated that such nonlinear system behaves better in response to fairly arbitrary inputs than linear system having 15 times the natural frequency. It is also indicated that a third-order system may similarly benefit.

L. Becker, USA

3541. Oldenburger, R., Optimum nonlinear control, *Trans. ASME* **79,** 3, 527-546, Apr. 1957.

This very interesting paper is concerned with the response of a controlled system after an initiating disturbance has died out—relay-type or off-on servomechanisms. Author treats actually servomechanisms in general where the rate of change of the controlling variable with respect to the time is bounded, and when this rate can be made to assume arbitrarily any value between its extreme values. Attention is concentrated on several of the simpler cases, and all possible initial modes of operation of each are examined. The influence of damping in system is treated also. The results of theoretical studies are given with practical compromises, and all results have been verified in the laboratory by electronic and other means on simulated and actual engines. Some of these results are shown in figures.

The discussers have a very good opinion of this lucidly written paper on a difficult and currently interesting phase of control theory [AMR **10,** Rev. 19; **10,** Rev. 629].

D. Raskovic, Yugoslavia

3542. Stout, T. M., Basic analysis methods for nonlinear control systems, *Instrum. and Automat.* **30,** 2, 262-267, Feb. 1957.

Phase-plane and describing-function methods for nonlinear control systems are discussed in detail. Extensive bibliography is attached. R. N. Arnold, Scotland

3543. Letov, A. M., The problem of the stability condition in the theory of automatic control (survey) (in Russian), *Tr. 2-go Vses. soveshch. po teorii avtomat. regulirovaniya* **1,** Moscow-Leningrad, Izd-vo AN SSSR, 79-104, 1955; *Ref. Zh. Mekh.* 1956, Rev. 2662.

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

3544. Andronov, A. A., and Bautin, N. N., The theory of course stabilization of an aircraft in a neutral altitude by means of an automatic pilot with a constant-speed servomotor. I. Case of absence of a no-response region (in Russian), *Izv. Akad. Nauk. SSSR, Otd. tekh. Nauk* no. 3, 3-32, 1955. *Ref. Zh. Mekh.* 1956, Rev. 4194.

A detailed exposition of the theory of point transformation of surfaces applied to the problem of course stabilisation in an aircraft in a neutral altitude by means of an automatic pilot with feedback and a constant-speed servomotor. In the formulation of the problem, the existence of a region of insensitivity of the servomotor is postulated. The structure of the phase-space of the system is described and the character of its perturbed motion within this space is defined. The conditions are established which must be applied to the parameters of the automatic pilot in order to insure the stability of the systems as a whole; these correspond to the results obtained earlier, by substantially different methods, by B. V. Bulgakov, [*Dokladi Akad. Nauk SSSR*, p. 37, 1942], as well as A. I. Lourie and V. N. Postnikor [*Prikl. Mat. Mekh.* no. 8, p. 3, 1944]. A brief summary of the results has already been communicated by these authors, *Dokladi Akad. Nauk* **43,** no. 5, 1944.

Courtesy Referativnyi Zhurnal A. M. Letov, USSR
Translation, courtesy Ministry of Supply, England

3545. Eckman, D. P., Taft, C. K., and Schuman, R. H., Electrohydraulic servomechanism with an ultra high-frequency response, *Trans. ASME* **79,** 3, 455-463, Apr. 1957.

Paper presents the results of an analysis of a specific design of a positional servomechanism. The results of these analyses cannot be compared with the performance of the constructed item, for some changes were made in its design prior to production.

The system considered involved the control of a hydraulically operated piston in a cylinder. Fluid was fed into the cylinder through a valve by means of a torque motor driven by an amplifier. Error sensing was done with a vacuum-tube displacement gage whose output was then applied to the torque amplifier. An additional feedback loop, consisting of a differential transformer and amplifier, was applied across the torque-motor-amplifier combination.

Paper is of interest to designers of such mechanisms in two respects. In the first place, this being a nonlinear device, the analysis is based upon a linearization about an operating point. This analysis is then compared to a solution of appropriate nonlinear differential equations as determined by an electronic differential analyzer. This comparison shows that the linearization is fairly dependable for this mechanism. In the second place, the analysis shows that the main lag in the system occurs in the torque motor and its associated amplifier and that developments leading to the fabrication of fast hydraulic servos could well concentrate on this portion of the system. H. M. Trent, USA

3546. Shearer, J. L., Nonlinear analog study of a high-pressure pneumatic servomechanism, *Trans. ASME* **79,** 3, 465-472, Apr. 1957.

A detailed analog simulation was made in order to evaluate the effects of nonlinear valve characteristics, nonlinear ram-chamber compliance, and coulomb friction in the ram on the dynamic performance of a high-pressure pneumatic servomechanism that had been studied previously with a linearized analysis. This analog

study revealed that a major part of the discrepancy between measured frequency-response characteristics computed from a linearized analysis is caused by coulomb friction in the ram. The other nonlinearities turned out to have an insignificant effect on the results.
From author's summary by Robert M. Stewart, USA

Vibrations, Balancing

(See also Revs. 3595, 3746)

3547. Ellington, J. P., and McCallion, H., The analysis of transient vibration data, *J. roy. aero. Soc.* **60,** 550, 679–680, Oct. 1956.

Authors give a new proof of a method in which records of transient vibrations of linear systems can be analyzed to give the damping factor and frequency of each mode of vibration associated with a given motion. The method requires the solution of a characteristic algebraic equation of degree n. With present high-speed computers this should not prove to be an insurmountable obstacle. Reviewer believes the method has merit and should be especially useful to aeronautical engineers in connection with flight flutter tests. E. J. Scott, USA

3548. Manolov, S., Existence of small periodic motions around the position of relative stable equilibrium of a mechanical system (in Russian), *Prikl. Mat. Mekh.* **19,** 4, 493–499, July/Aug. 1955.

Author considers a system of n ponderable beams of equal length and equal mass. The beams are connected one to another to form a compound physical pendulum with parallel axis. The first beam is suspended on a massless horizontal arm which is moving about a vertical axis with angular velocity ω.

It is shown that, for convenient values of ω and for convenient initial conditions, the system of beams will execute small oscillations about the vertical position, which is a position of stable relative equilibrium. The mathematical treatment leads to a characteristic equation having negative and simple roots. In the special case $n = 2$, the conditions for ω are found which are sufficient conditions of stability. J. Beranek, Czechoslovakia

3549. Hertig, R. R., Elastically supported solid. Part I and II (in Spanish), *Cienc. y Tecn.* **121,** 611, 98–119, July 1956; **121,** 612, 8–33, Aug. 1956.

Author considers successively (a) the elastic restraint and its reactions from a static point of view; (b) dynamic analysis of a body with elastic restraint, considering free vibrations, excitation by harmonic or rotating forces or harmonic motion; (c) plane motion (with a numerical example); (d) concurrent or parallel springs; (e) technical applications to engines, electric motors, automobiles, etc.

In analyzing plane systems, an original general solution for determining the natural frequencies for any position and direction of the elastic restraint is given. A. M. Guzman, Argentina

3550. Crawford, L., Piping under dynamic loading, *J. Amer. Soc. nav. Engrs.* **68.** 2, 345–370, May 1956.

The consequences of failure in certain types of piping system (e.g., containing radioactive materials) are so grave that preliminary vibration and shock analysis is desirable to assure their safety. Author approximates the system as a series of point masses, calculates the corresponding influence coefficients, and computes the natural frequencies and mode shapes in orthodox fashion. He discusses the procedure in considerable detail, with special comment on how the characteristic features of piping systems affect the analysis. He then treats the case where the system's external supports (anchor, hangers) are given prescribed initial motions, and describes possible procedures when only shock spectrum data are available at the supports. The application of computers is treated briefly, with emphasis on the importance of setting up very general computation routines, the special cases being taken care of by suitable standard subroutines. Appendices are devoted to references, an outline of the analytical procedure, and to proofs of various theorems on vibrations, so that the paper is in some respects self-contained. J. L. Lubkin, USA

3551. Eichelbrenner, E.-A., Numerical calculation of the aerodynamic damping of the vibration of compressor blades, *Rech. aéro.* no. 46, 7–14, 1955.

A method previously developed by Legendre [AMR **9,** Rev. 249] is applied to calculate the aerodynamic damping of a special case of blade cascade vibration. Results are compared with calculations for isolated airfoil. It is found that the region of instability increases due to effect of cascade; especially at low frequencies.
L. S. Dzung, Switzerland

3552. Weaver, F. L., and Prohl, M. A., High-frequency vibration of steam-turbine buckets, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56–A–119, 9 pp.

3553. Doi, S., and Kato, S., Chatter vibration of lathe tools, *Trans. ASME* **78,** 5, 1127–1134, July 1956.

Authors have made an interesting contribution toward the understanding of the nature of tool vibration commonly known as "chatter." The study of this type of vibration was made on a lathe. Records of tool work displacement was obtained by light beams through an optical system. Authors have attributed the energy necessary to sustain the self-excited vibrations of tool and work to a lag between horizontal cutting force and horizontal work oscillation. An analytical derivation of a single-degree vibrating system is presented to confirm experimental findings.
M. Martellotti, USA

3554. Halliday, J., Boiler vibration caused by combustion gas flow, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56–A–216, 4 pp. + illus.

Wave Motion in Solids, Impact

(See also Revs. 3550, 3572, 3838, 3871)

3555. Skalak, R., Longitudinal impact of a semi-infinite circular elastic bar, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56–A–37, 6 pp.

Author transforms the Pochhamer-Chree equations [Love: "Theory of elasticity," Cambridge, 4th. ed., 1927, p. 287] and introduces the initial conditions corresponding to the impact problem. He considers the inverse of the transforms as contour integrals and deduces results for large values of the time after the initial impact. The approximation involves an Airy integral, with the result that the theory predicts a dispersion of the wave front and a damped oscillation immediately behind it. These features are absent from the elementary theory, but have been observed experimentally by Davies [*Phil. Trans. roy. Soc. Lond.* (*A*) **240,** p. 443, 1948].
J. M. Jackson, Scotland

3556. Maryamova, F. A., The transverse impact of an elastic body on a beam, *Izv. Kievsk. politekb. in-ta* **16,** 6–13, 1954 (1955); *Ref. Zb. Mekh.* 1956, Rev. 4678.

A functional equation is set up for the value of the reciprocal pressure between the body and the beam during the impact. The influence of rotational inertia and the shearing force are considered by direct integration of the equation of flexural vibrations of the beam with hinge-supported ends under the action of a constant force applied at the center of the beam.

At the point of application of the force ($x = 0$) it is assumed that $\partial y/\partial x = 0$ (y bending deflection of the beam with supported ends, $x = \pm 1$). This condition, assumed in the abstractor's paper

[*Prikl. Mat. Mekh.* 1948, 12, (3), 287] has subsequently been contested by a number of writers [see *Ref. Zh. Mekh.* 1954, Rev. 5748; 1955, Rev. 378].

Abstractor takes the opportunity of pointing out that nonobservance of the above-mentioned condition leads to a discontinuity in the angle of inclination of the tangent to the elastic line of the beam at the point $x = 0$, which is contrary to the usual physical conceptions. Ya. S. Uflyand, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

3557. Craggs, J. W., The propagation of infinitesimal plane waves in elastic-plastic materials, *J. Mech. Phys. Solids* **5,** 2, 115–124, Mar. 1957.

Paper is an interesting study of the propagation of stress waves in an elastic-plastic material, with special reference to interactions between loading and elastic unloading waves. Effect of strain rate is not included as the author contends that since the strain-rate effect is assumed in the stress-strain curve of an *element*, .. "experimental evidence is not yet adequate for a final decision on the point...."

Reviewer does not agree. H. N. Abramson, USA

3558. Pao, Y.-H., Extension of the Hertz theory of impact to the viscoelastic case, *J. appl. Phys.* **26,** 9, 1083–1088, Sept. 1955.

Paper considers impact of viscoelastic body against rigid body. Laplace transform of the Hertz's solution is considered to give the viscoelastic solution in terms of the creep function. Typical cases are presented. Solution is open to some question since details of boundary condition at surface point which lies inside the maximum area of contact but which is free for part of the impact are not considered precisely. This difficulty is stated to give dimensions of area of contact somewhat larger than they should be.

E. H. Lee, USA

3559. Petrashen', I. G. I., Wave propagation in laminar isotropic media incorporating inclined strata (in Russian), *G. I. Ucb. zap. Leningr. un-ta* no. 177, *Ser. matem. nauk* no. 28, 105–147, 1954; *Ref. Zh. Mekh.* 1956, Rev. 4667.

A method of contour integrals is described for the solution of the problem of wave propagation in a medium with inclined strata. The problem is dealt with in the two-dimensional form, and the process is investigated only up to the point at which the perturbation reaches the point of intersection of the strata.

The paper contains no new information, since the problem in question is solved by the method of "functionally invariant equations" in a simpler and more convenient form [V. I. Smimov, S. L. Sobolev, *Tr. Seismol, in-ta. AN SSSR,* 1932, (20), 1953, (29)].

The author's consideration of the three-dimensional problem lacks concreteness. S. L. Sobolev, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

3560. Kuzhiy, A. I., and Shevelo, V. M., The influence of incomplete elasticity on the dynamic forces in a rope of variable length, analyzed by an asymptotic method (in Russian), *Prikl. mekhanika* **1,** 1, 41–50, 1955; *Ref. Zh. Mekh.* 1956, Rev. 4845.

The purpose of the present investigation is to demonstrate that the incomplete elasticity of a cord of variable length has a material influence both quantitatively and qualitatively on the behavior of the dynamic forces arising during the lifting of the load. It is assumed in this investigation that the law of variation of the hoisting rate (rotational speed of the winding drum) can be described by a trapezoidal broken line. Qualitative analysis leads the author to the conclusion that for a given hoisting rate $v_c = v_0 + at$ it is possible to indicate a particular limiting value of the coefficient of incomplete elasticity α_{np} at which, for all values of $\alpha < \alpha_{np}$, the forces in the cord will grow, while for $\alpha > \alpha_{np}$ they will decrease. The coefficient α characterizes the absorption of energy by the oscillations of the cord. N. V. Zvolinskii, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

3561. Karapetian, V. V., Determination of the pressure of an interference-affected wave on a vertical structure by means of electro-hydrodynamic analogies (in Russian), *Trudi n.-i. in-ta. osnovanye i fundamentov.* no. 25, 62–84, 1955; *Ref. Zh. Mekh.* 1956, Rev. 4465.

A detailed description is given of the known electro-hydrodynamic analogy method and its application to the measurement of wave pressures. Measured results are quoted.

For comparison, a pressure diagram on the Saint-Floud method is given; the pressures calculated by the latter are higher than those determined by the author. S. S. Voit, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

Elasticity Theory

(See also Revs. 3549, 3586, 3601, 3640, 3641)

Book—3562. Dinnik, A. N., Selected works. Vol. 2. The application of Bessel functions in problems of the theory of elasticity (in Russian), edited by A. M. Penkov, Kiev, Izd-vo Akad. Nauk USSR, 1955, 244 pp. + illus; *Ref. Zh. Mekh.* 1956, Rev. 3821.

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

3563. Bulyin, I. E., Tangential stresses in the flat bending of a curved bar (in Russian), *Sb. rabot. stud. naucb. o-va Penzensk. industr. in-ta, Penza,* 153–158, 1955; *Ref. Zh. Mekh.* 1956, Rev. 4716.

An elementary derivation is given of the equation for the tangential stresses in a beam of rectangular cross section. An error has been made in calculating the equivalent normal forces produced in the cross section by the bending moment.

Courtesy Referativnyi Zhurnal A. A. Popov, USSR
Translation, courtesy Ministry of Supply, England

3564. Nowacki, W., The state of stress in a thin plate due to the action of sources of heat, *Publ. int. Assn. Bridge struct. Engng.* **16,** 373–398, 1956.

A highly academic treatment of thermal stresses at various locations of a strip of plate with infinite length, semi-infinite strip of plate, and a rectangular plate. Deductions are based on a well-formulated derivation of analogy between the differential equation for thermal potential of displacement and a differential equation for thin plate deflection due to a concentrated load; the first expression being derived for a steady temperature field and the second for simply supported plates. The analogy is presented in very convincing detail, concluding with a theoretical method for elimination of shear stresses at the plates' edges.

The entire paper offers an inspiring analysis, and the part treating the rectangular thin plate is a valuable contribution for applied mechanics. Although the rather complex mathematical treatment might appear of lesser usefulness for average engineering practices, its value for advanced projects, such as in the field of nuclear energy and space flight, is quite significant.

C. R. Bell, USA

3565. Norbury, J. F., Thermal stresses in disks of constant thickness, *Aircr. Engng.* **29,** 339, 132–137, May 1957.

Author obtains routine solution of thermoelastic equations in polar coordinates for case of plane stress with axial symmetry.

Solutions are given for circular disks and annuli of constant thickness on assumption that temperature is proportional to nth power of distance from axis. Cases $n = 1/3, 1/2, 1, 2, 3$ are considered and compared. Author reaches expected conclusion that value of n exerts strong influence on stress distribution. He shows that, for stationary disk, $n = 1$ gives optimum safety on maximum shear-stress theory of failure.

In deriving the basic differential equation (Appendix I), author overlooks the fact that, if thickness of disk is not constant, he must either abandon plane stress assumption (in which case this differential equation no longer holds) or he must introduce tractions on the surfaces of the disk in order to maintain the state of plane stress. Since, in the main body of the paper, the thickness of the disk is taken to be constant, this oversight does not affect the validity of his results.

Author indicates that his investigation has bearing on the design of cooling systems for turbine disks.

G. Bosson, Australia

3566. Bader, W., Numerical determination of thermal stresses (in German), *ZAMM* **36,** 9/10, 331–339, Sept./Oct. 1956.

Particular solutions for Poisson's equation of the displacement potential are determined. A simple method of solution for the field of displacement, which is to be superposed in order to fulfill the boundary conditions, is proposed. As an example of the method, a circular cylinder with ends kept at constant difference of temperature and radiation at the curved surface is examined. Graphs for the stress and the temperature distributions for cylinders of various length-to-diameter ratios are given.

T. C. Lin, China

3567. Lessen, M., Thermoelasticity and thermal shock, *J. Mech. Phys. Solids* **5,** 1, 57–61, Nov. 1956.

This brief but highly technical paper shows by thermodynamic reasoning that usual Fourier equation expressing time rate of temperature change as a function of diffusivity and temperature gradient should include a term expressing dependence on rate of dilatation, with a generalized Hooke's law following as consequence of thermodynamic relations rather than being an independent postulate. It is further shown that the problem of initial thermal shock (sudden temperature change over very shallow depth of surface) can be solved by usual Fourier equation if diffusivity is modified by certain factor. When depth of penetration is no longer small, solution can be obtained by perturbation expansion. In reviewer's opinion, results should be further recast for convenience in practical applications. C. W. Smith, USA

3568. Hemp, W. S., Thermo-elastic formulae for the analysis of beams, *Aircr. Engng.* **28,** 333, 374–376, Nov. 1956.

The formulas obtained in this paper represent a generalization of the so-called engineering theory of bending and of the Wagner-Kappus torsion theory to include the effects of nonuniform temperature distribution. Kinematically, allowance is made for overall longitudinal extension, for curvature in the two principal planes, for twist, and for cross-sectional warping of the kind occuring in Saint Venant's torsion theory. Author deals briefly and concisely with the concept of free energy, principle of stationary free energy, specification of beam deformation, formula for the free energy in a beam, virtual work of the external forces, variational equation of equilibrium and load-deformation relations, stress analysis and buckling problems. The notation is clear, text lucid. The approach is useful. C. R. Mischke, USA

3569. Guttman, S. G., The determination of the heat stresses in harmonic temperature fluctuations (in Russian), *Izv. Vses. n.-i. in-ta gidrotekh.* **47,** 72–102, 1952; **51,** 23–53, 1954; *Ref. Zh. Mekh.* 1956, Rev. 4615.

The temperature at the surface of the body is assumed to be determined as a sinusoidal time function. It is required to find the temperature distribution and elastic stresses, neglecting the inertia forces. The cases of a slab, hollow sphere, cylindrical pipe, and cylindrical cavity are examined.

Courtesy Referativnyi Zhurnal E. I. Grigolyuk, USSR
Translation, courtesy Ministry of Supply, England

3570. Froyd, R. K., Note on a problem considered by Tiffen, *Quart. appl. Math.* **14,** 4, 426–428, Jan. 1957.

3571. Malinin, N. N., Twist of turbine blades, *Izv. Akad. Nauk Otd. tekh. Nauk* no. 4, 23–46, Apr. 1954.

Experimental Stress Analysis

(See also Rev. 3601)

3572. Frocht, M. M., Flynn, P. D., and, Landsberg, D., Dynamic photoelasticity by means of streak photography, *Proc. Soc. exp. Stress Anal.* **14,** 2, 81–90, 1957.

A bibliography of the application of high-speed motion photography to dynamic photoelasticity is presented. Authors outline briefly the characteristics of various methods and describe their drum camera in detail. It contains two separate lens and film systems, designed to record the stress histories of selected orthogonal planes. Calculated equivalent exposure time is given as 2/3 microsecond. A photoflash no. 22 lamp, together with a Baird filter, was used to secure monochromatic light. Linograph Ortho paper, developed in Kodak SD-19a, is recommended. Complete details of the experimental setup, as well as a few of the photographs, are presented. C. E. Balleisen, USA

3573. Stein, P. K., Individual strain gage desensitization, *Proc. Soc. exp. Stress Anal.* **14,** 2, 33–36, 1957.

A procedure is shown for arranging a circuit to desensitize a single strain gage in a Wheatstone Bridge. Methods for estimating errors are shown, and a technique is demonstrated whereby temperature effects may be minimized or eliminated.

From author's summary

3574. Geiger, R. C., and Sherlock, I., External strain-gage instrumentation for transient elevated temperatures, *Proc. Soc. exp. Stress Anal.* **14,** 2, 117–130, 1957.

A method of measuring strains using high-temperature foil strain gages was developed for use at 400–500 degrees Fahrenheit. The strain errors exceed those normally allowed; however, improvement can be made if the compensating gage is mounted on the test specimen in a unilateral stress area. From authors' summary

3575. Vigness, I., Magnetostrictive effects in wire strain gages, *Proc. Soc. exp. Stress Anal.* **14,** 2, 139–148, 1957.

The alignment of magnetic domains by strain, in ferromagnetic materials used for strain-gage wire elements, causes a nonlinear change of electrical resistance with elastic strains. For strongly magnetostrictive materials, such as nickel, this effect is predominate. For weakly magnetostrictive materials, such as the isoelastic wire used in SR-4 type-C gages, this gives rise to a 3% change in gage-factor for elastic strains. Magnetostrictive wires that have been conditioned by carrying a relatively large electric current will have the circumferential component of the magnetic field associated with its magnetic domain elements aligned in a preferred direction by the magnetic field associated with the current. When a wire thus conditioned is subjected to a change of strain, the circumferential magnetic field will be disturbed and a voltage will be generated along the length of the wire. These self-generated voltages may approach 1 millivolt for type-C gages and they may be several millivolts for nickel gages.

From author's summary

3576. McWhirter, M., and Duggin, B. W., Minimizing creep of paper-base SR-4 strain-gages, *Proc. Soc. exp. Stress Anal.* **14,** 2, 149–154, 1957.

A series of room-temperature creep tests were performed to evaluate a group of paper-base bonded resistance-wire strain gages which were mounted using a technique developed to minimize creep. The gages were held at a constant strain of 2900 micro-inches per inch for a period of 63 days. Apparent strains, as indicated by the gages, were observed during this period and for twenty-four days after removal of the load.

It was found that certain paper-base gages could be used satisfactorily in the measurement of long-term strains of the magnitude used within an accuracy of approximately one per cent, whether used in tension or compression. The creep rates in tension and compression were not significatnly different in the types tested.

From authors' summary

3577. Cunningham, J. H., and Yavorsky, J. M., The brittle lacquer technique of stress analysis as applied to anisotropic materials, *Proc. Soc. exp. Stress Anal.* **14,** 2, 101–108, 1957.

Nonapplicability of photoelasticity techniques in cases where directions of principal stresses and strains do not coincide (as with anisotropic materials) is discussed. Method is given for determining principal stresses in orthotropic materials from principal strains measured by brittle lacquer techniques. Experimental data from test on wood agree with theory. W. D. Jordan, USA

3578. Durelli, A. J., and Riley, W. F., Developments in the grid method of experimental stress analysis, *Proc. Soc. exp. Stress Anal.* **14,** 2, 91–100, 1957.

This paper describes a method recently developed for embedding a grid network within a sheet of photoelastic material. By embedding the grid in the material many of the limitations of the grid method for experimental stress analysis are removed.

Since the separation of principal stresses is a rather simple procedure by means of a grid network, the improved techniques make the method an extremely valuable complement of photoelasticity. The method also can be used independently if the elastic constants of the material are known, since the grid measurements yield all of the information needed to completely solve a stress analysis problem. In addition, the grid method can be used for dynamic, three-dimensional, and plastic deformation studies, either independently or in conjunction with photoelasticity.

To evaluate the method, grid measurement results were compared with results from photoelastic measurements and electrical resistance-wire strain-gage measurements. The results from all three types of tests were in excellent agreement. Since relatively large deformations are required for accurate measurements, the method is limited, however, to those problems in which large deformations of the plastic do not produce appreciable changes in the boundary conditions. G. Gerard, USA

3579. Ghosal, H. N., Measurement of strain in structures by electronic methods, *J. Instn. Engrs., India* **37,** 6, part 2, 645–658, Feb. 1957.

3580. McClure, G. M., and Abraham, E. D., Stress analysis in the design of a mobile home, *Proc. Soc. exp. Stress Anal.* **14,** 2, 1–10, 1957.

3581. Schultz, T. J., Measurement of membrane tension, *Rev. Sci. Instrum.* **26,** 6, 624–625, June 1955.

Rods, Beams, Cables, Machine Elements

(See also Revs. 3539, 3548, 3555, 3560, 3563)

3582. Griffin, K. H., Certain methods of stress-analysis of rectangular multi-web box beams, *Coll. Aero. Cranfield Rep.* no. 108, 12 pp. + 8 appendixes + 3 figs., Dec. 1956.

Comparison is made between stress distribution computed on the basis of discrete webs and that obtained for a web continuum. The agreement between the two methods is satisfactory for structures typical of normal practice, when the accuracy of results does not exceed practical stressing requirements.

J. Solvey, Australia

3583. Fosca, V., and Alexandrescu, A., Elastic deflection of beams with linear increase of depth (in Rumanian), *Indust. constr. Mater. constr.* **7,** 6, 351–362, 1956.

Beams having linear one-direction and symmetrical slopes are theoretically investigated. Simplified formulas similar to those with constant moment of inertia are derived and coefficients introduced depending on characteristic variables, such as maximum and minimum depth and moments of inertia, types of the cross section and spans. Values of these coefficients for typical cross sections are tabulated and presented in diagrams. References are made to other methods and publications by Filomenko-Borodici, G. G. Karlsen, P. R. Voinea, Krilov. J. J. Polivka, USA

3584. Renne, I. P., The limiting conditions in the transverse bending of rectangular beams (in Russian), *Trudî. Tulsk. mekh. in-ta* no. 7, 163–174, 1955; *Ref. Zh. Mekh.* 1956, Rev. 4659.

A connection is established between the bending moment and the transverse force for the rectangular cross section of a beam subjected to transverse bending. The relationship between the stress intensity and the deformation of the material is approximated by an exponential function.

Comparisons are made with the approximate solution of the same problem by N.I. Bezhkhov, *Vestn. inzh. i tekhnikov,* no. 10, 1936; A. R. Rzhanitskin, "Calculation of structures with regard to the plastic properties of materials", Stroyvoenmorizdat, 1949.

Courtesy Referativnyi Zhurnal N. I. Bezukhov, USSR

Translation, courtesy Ministry of Supply, England

3585. Anevi, G., Experimental investigation of shear strength and shear deformation of unstiffened beams of 24 S-T alclad with and without flanged lightening holes, *SAAB Aircr. Co. Linköping* TN 29, 59 pp., Oct. 1954.

In the investigation dealt with in this report a new test procedure has been used, which gives considerably better agreement with actual conditions than has been the case with similar investigations carried out previously. The new test procedure and the test rig are described in some detail, and comparisons are made with corresponding methods and arrangements used in investigations by Karl Schüssler and Paul Kuhn.

The direct test results are shown in tables and discussed. Ultimate loads, shear deformations, buckling observations, and material tests are each treated separately. An evaluation of the ultimate loads takes into account the deformation criteria applied at SAAB. A simple reduction of the ultimate shears to standard has been carried out.

A proposal has been put forward for calculating the shear strength and the initial shear deformation. Comparisons have been made with design procedures suggested in earlier investigations by Schüssler and Kuhn.

The results of a series of fatigue tests on unstiffened beams with lightening holes are shown. From author's summary

3586. Johnson, W., and Mellor, P. B., The centre of shear for a material having a non-linear stress-strain curve, *Appl. sci. Res.* (*A*) **6,** 5/6, 467–477, 1957.

The position of the shear center for thin-walled beams having semicircular and channel cross sections is investigated when the material stress-strain relation is a simple power law. The assumptions of the usual engineering theory of bending are otherwise retained. The location of the shear center is found to be dependent on the strain exponent n and on the cross-section shape, but independent of the applied load below "a certain magnitude." The effect of n on the shear flow distribution is shown for the semicircular cross section. Results are compared with those of Handelman [AMR **5,** Rev. 1331].

A. D. Topping, USA

3587. Johnson, L. G., The use of high-speed computers in the design and appraisal of helical gears, ASME Ann. Meet., New York, N. Y. Nov. 1956. Pap. 56-A-142, 12 pp.

Having proposed a given set of dimensions and proportions of machine elements for a particular application, the designer is faced with the problem of obtaining a reliable appraisal of his proposal quickly. Evaluation of the design mathematically is cumbersome and time-consuming. Using helical-gear design as an example, author explains how the use of the high-speed computer aids in evaluating the design problem.

From author's summary

Plates, Disks, Shells, Membranes

(See also Revs. 3550, 3564, 3581, 3596, 3597, 3598, 3599, 3620, 3622)

3588. Pinsky, M. G., The stress concentration in the bending of thin plates with circular washers by inertia forces (in Russian), *Izv. Tomsk. politekh. in-ta.* **75,** 195–209, 1954; *Ref. Zh., Mekh.* 1956, Rev. 4622.

The problem is examined of the stress concentration in the bending of thin infinite plates weakened by a cutout into which an absolutely rigid washer free from all moments is welded, and also of the case where a moment is applied to such a washer.

The problem is solved in functions of a complex variable, on the assumption that the region of the plate is represented on the exterior of a circle by the function

$$z = \zeta + m\zeta^{-n}$$

where n is a real integer.

Particular cases are examined and curves are given. In the abstractor's paper [*Dokladi Akad. Nauk USSR* no. 4, 1949], the more general problem is examined of the bending of plates weakened by a curvilinear opening with the edge reinforced by an annular bar the region of which, together with the region of the plate, is represented on the circumference of the unit circle by a rational function. M. P. Sheremet'ev, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

3589. Postnov, V. A., Resistance and behavior beyond the elastic limit of thin plates stiffened by longitudinal ribs (in Russian), *Trudi Leningr. korablestorit. in-ta* no. 15, 26–41, 1955; *Ref. Zh. Mekh.* 1956, Rev. 4648.

The paper refers to large deflections under axial compression supported on their transverse edges and reinforced by a number of longitudinal stiffening ribs. The influence of reinforcing ribs on the work of the plate after the plate and the ribs have lost stability is also investigated. The solution of the problem is obtained by the generalized Bubnov-Galerkin method. A chart is included showing the influence of the stiffness of the ribs on the value of the coefficient of reduction for a plate of concrete dimensions. M. S. Komishin, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

3590. Naghdi, P. M., The effect of transverse shear deformation on the bending of elastic shells of revolution, *Quart. appl. Math.* **15,** 1, 41–52, Apr. 1957.

Paper is an interesting development of the title subject. Author reduces the three equations of equilibrium to two differential equations for shells of revolution, using the stress-strain relations and a compatability condition. When transverse shear deformation is neglected these latter equations reduce to those given previously by E. Reissner. Using a complex form, the analysis is reduced to the solution of a single inhomogeneous differential equation. Author then discusses somewhat at length the solution of the corresponding homogeneous equation by the method of asymptotic integration.

Relationship of the development in the paper to previous work by the author and several other authors is briefly discussed.

W. H. Hoppmann, USA

3591. Csonka, P., Expedient shaping of calotte shells over rectangular bases (in German), *Publ. int. Assn. Bridge struct. Engng.* **16,** 71–84, 1956.

Membrane forces can be found simply by a proper choice of shell form and stress function. Closed formulas for a transfer shell with generator curves similar to cycloids and approximate formulas for flattened paraboloid shells are presented.

H. Schaefer, Germany

3592. Mikeladze, M. Sh. The plastic equilibrium of a multilaminar anisotropic shell (in Russian), *Dokladi Akad. Nauk* SSSR (*N.S.*) **102,** 2, 229–232, 1955; *Ref. Zh. Mekh.* 1956, Rev. 4656.

On the assumption that the laminae forming the shell are themselves orthotropic and that the anisotropic planes in it are identically oriented, with constant stress over the depth of each layer, the end relationships are established between forces and moments for the case of plastic equilibrium of a multilaminar anisotropic shell. Numerical calculations for a semi-infinite, long shell are compared on the assumption of constant stress through the depth of the layer and satisfaction of the Kirchhoff-Llave hypothesis. Khuan Ke'-yazhi, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

Buckling Problems

3593. Gasser, H. H., The buckling of linked columns (in German), *ZAMP* **8,** 1, 64–71, Jan. 1957.

Paper computes the buckling loads of columns with one end built-in, the other end hinged or built-in, and having one or two hinges between the ends. Y. C. Fung, USA

3594. Lee, L. H. N., and Ades, C. S., Plastic torsional buckling strength of cylinders including the effects of imperfections, *J. aero. Sci.* **24,** 4, 241–248, 264, Apr. 1957.

The torsional buckling strength of a cylinder in the plastic range has been determined. An energy solution and a more exact solution, both based on a plastic stress-strain relationship given by the simple deformation theory, are presented. Close agreement between the two solutions is found. The effects of large deflections and imperfections on buckling strength are analyzed. For two groups of experimental results used for comparison, the effects of geometrical imperfections in the plastic range are negligible. The theoretical results are found to be in good agreement with the experimental results.

From authors' summary by M. Botman, Canada

3595. Klein, B., Determination of effective end fixity of columns with unequal rotational end restraints by means of vibration test data, *J. roy. aero. Soc.* **61,** 554, 131–132 (Tech. Notes), Feb. 1957.

Paper extends work by Stephens [*J. aero. Sci.* **4,** 2, 54–60, Dec. 1936] in calculating relationship between end fixity and natural frequency in struts with various end conditions. Method calculates curvature/slope ratio at each end of strut in buckling mode and identifies each with corresponding ratios from two vibration modes. From buckling mode, end fixity is obtained and this is then related to the two frequencies concerned. A few values are tabulated. K. H. Griffin, England

3596. Kempner, J., Pandalai, K. A. V., Patel, S. A., and Crouzet-Pascal, J., Postbuckling behavior of circular cylindrical shells under hydrostatic pressure, *J. aero. Sci.* **24,** 4, 253–264, Apr. 1957.

The postbuckling behavior of initially perfect, thin-walled, circular cylindrical shells under hydrostatic pressure is investigated with the aid of the principle of stationary potential energy together with appropriate approximate deflection functions. Calculations show that postbuckling equilibrium configurations exist for loads greater than as well as loads slightly less than the critical load calculated from small-deflection theory. Loads less than the critical load are obtained only for a finite range of a parameter indicative of shell geometry. For loads corresponding to radial displacements of the order of the shell thickness, it is found that the number of circumferential waves remains essentially constant with increasing deflection and equal to the number of waves developed at buckling.

From authors' summary by M. Botman, Canada

3597. Wenk, E., Jr., and Kennard, E. H., The weakening effect of initial tilt and lateral buckling of ring stiffeners on cylindrical pressure vessels, *David W. Taylor Mod. Basin Rep.* 1073, 24 pp., Dec. 1956.

Internal or external ring stiffeners attached to a cylindrical shell that is subjected to external pressure are frequently observed to twist excessively when shell buckles. Authors consider a stiffener of T-shaped cross section with free edge of web of tee welded to cylinder. They suppose stiffener to be imperfect, so that web of tee tilts at constant angle with respect to generators of cylinder. Contraction of shell caused by external pressure imposes uniform radial load on attached edge of T-ring. Differential equation for resulting elastic deformation of ring is developed, and corresponding stresses in ring are investigated. Also, axisymmetric lateral buckling of an ideal T-ring is treated. Applications of theory to stiffeners with other cross-sectional shapes is discussed. H. L. Langhaar, USA

3598. Kirstein, A. F., and Wenk, E., Jr., Observations of snap-through action in thin cylindrical shells under external pressure, *David W. Taylor Mod. Basin Rep.* 1062, 15 pp., Nov. 1956.

Experimental results are reported for buckling of two unreinforced steel cylindrical shells subjected to external pressure. Shells were loaded by evacuation. They were so thin that they could be buckled without yielding. Experiments were designed to test snap-through theory. A postbuckling equilibrium state was found to exist at pressures below the observed buckling pressure, and below the critical pressure predicted by classical small-deflection theory. Structure could be made to jump into buckled configuration by slight impact when pressure was maintained below buckling pressure. When pressure was relieved, structure snapped back. Comparisons with large-deflection theories of Donnell and Langhaar-Boresi are given. Although end plates were soldered to shell, good agreement with theory for simply supported ends is indicated. H. L. Langhaar, USA

3599. Skory, I. A., and Darozhkin, I. V., The coefficient of lateral deformation (in Russian), *Tr. Mosk. aviats. tekhnolog. in-ta* no. 25, 112–118, 1954; *Ref. Zh. Mekh.* 1956, Rev. 4855.

A simplified method is advanced for determining the coefficient of lateral deformation μ. The general form of the equation suggested is

$$\mu = \frac{1}{k-1}\left(1 - \sqrt{\frac{1+\theta}{k}}\right) \qquad [1]$$

where ϑ is the relative volume. Assuming for relatively small deformations

$$k = \sqrt{1 + 2\epsilon_{11}} \approx 1 + \epsilon_{11}$$

authors find that Eq. [1] can be simplified:

$$\mu = \frac{1}{\epsilon_{11}}\left(1 - \sqrt{\frac{1+\theta}{1+\epsilon_{11}}}\right) \qquad [2]$$

For very small deformation

$$\mu = 0.5 - \frac{\vartheta}{2\epsilon_{11}} \qquad [3]$$

In consideration of the incompressibility of the material

$$\mu = \frac{1}{\epsilon_{11}}\left(1 - \frac{1}{\sqrt{1+\epsilon_{11}}}\right)$$

The results are given of experiments on the determination of the coefficient of lateral deformation μ. The experiments were made on strip steel samples, previously annealed.

Courtesy Referativnyi Zhurnal V. A. Sveshnikova, USSR
Translation, courtesy Ministry of Supply, England

3600. Galperin, I. I., Development of the theory of structural stability and of structural synthesis (in Russian), *Tr. 2-go Vses. soveshch. po teorii avtomat. regulirovaniya,* **1,** Moscow-Leningrad Izd-vo AN SSSR, p. 459, 1955; *Ref. Zh. Mekh.* 1956, Rev. 2663.
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

Joints and Joining Methods

(See also Rev. 3643)

3601. Tombach, H., Adhesive joints, *Mach. Design* **29,** 7, 113–120, Apr. 1957.

Paper treats plain lap joint between adherends with identical elastic properties and thickness, loaded in tension. It explains four methods of converting adhesive joint strength tests into systematic design data, with (reviewer is happy to see) appropriate cautions. Theoretical material is not new, but paper will be useful to the designer. One method of correlation is to plot joint strengths against DeBruyne's "joint factor" = *(adhesive layer thickness)*$^{\frac{1}{2}}$ ÷ *(adhesive thickness)*. Author also describes how to curve-fit strength test results to a power-law variation in "*overlap ratio*" = *(joint overlap)/(adherend thickness)*.

Last two methods explain how to curve-fit test results to two analyses, one due to O. Volkersen and the other to M. Goland and E. Reissner. The assumptions of these analyses are generally violated in strength tests, as author notes. Under these circumstances, the two theories simply become vehicles for approximately carrying over test results from one adherend material to another (some adhesive in both cases). This is sometimes possible, if both adherend materials show sufficiently good adhesion to the adhesive in question, but must always be verified by test. The appendix gives a few statistical formulas useful in the various curve-fitting operations. J. L. Lubkin, USA

3602. Pilia, F. J., and Minga, R. W., The application of inert-gas tungsten-arc welding to carbon-steel pipe, *Welding J.* **36,** 4, 363–370, Apr. 1957.

3603. Meredith, R., and Baird, B. L., Design and technique requirements for arc welding titanium in aircraft applications, *Welding J.* **36,** 4, 371–377, Apr. 1957.

3604. Daley, D. M., and Hartbower, C. E., Investigation of the mechanical properties of metal-arc welding Ti-6%, Al-4%, V, *Welding J.* **36,** 4, 185s-190s, Apr. 1957.

3605. Munse, W. H., and Alagia, J. S., Strength of brazed joints in copper alloys, *Welding J.* **36,** 4, 177s–184s, Apr. 1957.

3606. McDonald, A. S., Alloys for brazing thin sections of stainless steel, *Welding J.* **36,** 3, 131s–140s, Mar. 1957.

3607. Bohn, G. H., Silver-brazing lap joints in stainless steel tubing, *Welding J.* **35,** 9, 884–889, Sept. 1956.

Paper presents experimental data and calculations to show that, if the lap of a properly made silver-brazed joint in Type 300 Series stainless tubing with commercial mill tolerances is made three times the thickness of the tubing, the joint will be stronger than the tubing with internal pressure, tension stresses due to thermal expansion and dead load, or a combination of the two.

From author's summary

3608. Russell, W. E., and Wisner, J. P., An investigation of high-temperature vacuum and hydrogen furnace brazing, *NACA TN* 3932, 29 pp., Mar. 1957.

The vacuum and the hydrogen brazing of four heat-resistant alloys with two types of high-temperature brazing alloy were investigated. The effect of time at two brazing temperatures on the 1200F shear strength of joints and on the base-metal properties was studied.

Brazing techniques were evaluated for alloys that can be age-hardened and that contain titanium and aluminum in a vacuum as well as in dry hydrogen.

In general, results showed that of the two brazing alloys used, the boron-free alloy was less damaging to base metal than the boron-bearing alloy, but that shear joints made with the boron-bearing braze were stronger. Although it was thought that the primary difference between the alloys was boron content, the higher carbon of the boron-bearing alloy may be significant.

Furnace brazing temperatures and time at temperatures were important factors in lowering the tensile strength and elongation of braze-coated sheet-metal tensile specimens. The effects varied depending on the base metal and the brazing alloy used.

Shear specimens of all four base alloys brazed in hydrogen with both types of brazing alloy exhibited erratic joint coverage by the brazing alloys. The data indicated, however, that, if joint coverage was complete, vacuum and hydrogen brazing produced joint shear strengths of about the same magnitude.

From authors' summary

3609. Munse, W. H., and Cox, H. L., The static strength of rivets subjected to combined tension and shear, *Univ. of Ill. Engng. Exp. Sta. Bull* no. 437, 28 pp., 1956.

Design specifications do not provide for use of rivets subjected both to shear and tension. Tests were conducted on ¾-in., ⅞-in., and 1-in. rivets with grip from one to five inches, under four different shear/tension ratios. Rivets were driven into pairs of round blocks provided with shoulders. Blocks were mounted on split loading attachment. Single test jig allowed for various shear/tension combinations.

In preliminary testing, authors investigated: (a) difference in ultimate strength between rimmed, killed, or semi-killed rivet steel; (b) effect on ultimate strength of driving time; (c) idem of furnace temperature; (d) idem of soaking time. In main testing, 403 tests were conducted under shear ratios: 1.0 ÷ 0.0; 1.0 ÷ 0.577; 0.577 ÷ 1.0; 0.0 ÷ 1.0.

Results show: (a) is small (<5%), (b), (7–30 sec) and (c), (1800 F – 1950 F) are small; (d) is appreciable. On the basis of main tests, a nondimensional elliptical interaction curve is presented. Ultimate strength S of a rivet is $S = r.S_s$, with $r^2(1.777 + m^2) = 1.777 . (1 + m^2)$, S_s is ultimate strength of rivet in direct shear, and m tensile component/shear component.

Reviewer finds paper clearly presented and data interesting.

G. H. Beguin, Switzerland

3610. Stern, E. G., Plain-shank vs. threaded nails, *Virginia Polyt. Inst. Wood Res. Lab. Bull.* no. 27, 1–24, Dec. 1956.

Fully comparative tests were performed on plain-shank, fluted, and threaded nails of various types in order to determine the relative effectiveness of these nails in a number of wood species—immediately after driving as well as after such exposures of the nailed test planks as simulate accelerated service conditions.

In delayed withdrawal tests, the medium-carbon-steel fluted nails provided—in comparison with the effectiveness of low-carbon-steel plain-shank nails of same weight—on the average 1.6 times, that is, from 0.9 times to 2.2 times, the effectiveness; the tested threaded nails were from 2.8 to 9.8 times, with a grand average of 4.9 times, as effective as the plain-shank nails.

In light of these data on the effectiveness of these two types of deformed nails, it is necessary to differentiate between them, both in specifications and in use. From author's summary

3611. Stern, E. G., Holding power of large nails and spikes in dry southern pine, *Virginia Polyt. Inst. Wood Res. Lab. Bull.* no. 30, 1–12, Apr. 1957.

Test data are presented on the effectiveness of large plain-shank and annularly threaded nails and spikes driven into dry southern pine and tested immediately after driving.

The influences of depth of shank penetration and predrilling on the holding power of the fasteners are shown. On the average, the threaded nails and spikes proved, immediately after driving, to be 2¼ times as effective as the same size plain-shank fasteners.

A formula is presented to compute the holding power of large, bright annularly threaded Stronghold nails and spikes in dry predrilled southern pine, which is similar to the formula previously advanced for identical fasteners in dry predrilled hickory.

Consideration is also given to the particular advantages of using slender, threaded, hardened high-carbon-steel nails and spikes instead of the heavier low-carbon-steel fasteners of same lengths.

From author's summary

3612. Stern, E. G., Nails and spikes in creosote-pressure-treated southern pine poles and timbers, *Virginia Polyt. Inst. Wood Res. Lab. Bull.* no. 26, 1–20, Oct. 1956.

The availability of creosote-pressure-treated poles and timbers for structural purposes and the rapidly increasing erection of pole-type structures all over the country—especially for agricultural purposes, open-air theaters, and other open field structures, —calls for the availability of test and design data for nails and spikes in such preservatively treated wood. The data presented in this report should be of particular assistance to architects, engineers, and builders who wish to detail their designs fully and to issue complete specifications concerning the nailing procedures to be used for fastening to creosoted poles and timbers.

From author's summary

Structures

(See also Revs. 3585, 3600, 3610, 3611, 3612, 3852, 3856)

Book—3613. Pernot, P., Introduction to the calculation of statically indeterminate systems [Introduction au Calcul des Systemes Hyperstatiques], Paris, Gauthier-Villars, 1956, x + 398 pp.

The bulk of this book consists of sets of detailed worked examples of the computation of forces and deflections in elastic, statically indeterminate plane frameworks. The book is divided into three parts, in which the methods of moment distribution, slope-deflection, and strain energy are dealt with in turn. Each part opens with an explanation of the method under discussion and this is followed by thirty-six worked examples. The same examples are used in the three parts so a ready comparison can be made between the utility of the alternative approaches for a particular framework. In the sections on slope-deflection and strain energy, author derives analytic expressions for the moments before making numerical substitutions.

R. M. Haythornthwaite, USA

Book—3614. Merchant, W., and Bolton, A., An introduction to the theory of structures, London, Blackie & Son, Ltd., 1956 x + 210 pp.

As its title indicates, the book is an introductory text on the basic principles of the theory of structures, and forms a good guide for students who wish to start the subject from scratch. The twelve chapter headings, which are self explanatory, are: Statics; Beams; Trussed frameworks; Deflection of beams; Fixed-end and continuous beams; Stress and strain; Stress distribution in the interior of members; The use of theory in design; Earth pressures, retaining walls, rivet groups; Moving loads; Pillars; and Slope deflection and moment distribution. In the appendix is given a section on the connection between theory of structures and design codes, which in the opinion of the reviewer merits special attention and should have been placed at the beginning. Although the reader gets an impression that the elastic theory is not the last word in designing structures, no attention as such is devoted to a description of the plastic theory, which is now getting quite common even in Britian in the application of the design of building frames. Throughout the text the application of the theoretical principles is clearly stated; the basic and fundamental principles are not, however, made very clear. S. K. Ghaswala, India

3615. Hondros, G., and Kirkby, D. A., The use of wire models to solve the continuous Veirendeel girder, Parts I and II, *Civ. Engng. Lond.* **52,** 607, 51-54, Jan. 1957; **52,** 608, 171-172, Feb. 1957.

In structural engineering practice, frameworks are often met whose analysis is tedious by routine calculatory methods of statics. In such cases the idea may occur to determine moments arising in the bars by model analysis instead of computation. Author justifies the application of model analysis on the example of a continuous 6-panel Vierendeel girder. Moments are first computed and the results of calculation are compared to those measured on a wire model. The model is directly loaded by forces; end rotation and displacement of joints are measured and moments computed by the slope-deflection equation. In case of careful execution of the test, calculated and measured results diverge but little. Since the wire model is simple to produce and the test does not call for highly specialized measuring apparatus, the method presented is suitable for the solution of practical problems of two-dimensional complex frames.

In reviewer's opinion, in the preparation of the model it would be practicable to insert at the joints rigid disks, the dimensions of which are in proportion to those of the bars. Thereby the model would be still more similar to the actual structure than the sketch of the calculation. This would be of importance especially in the case of reinforced-concrete Vierendeel girders.

P. Csonka, Hungary

3616. Klein, B., A simple method of matric structural analysis, *J. aero. Sci.* **24,** 1, 39-46, Jan. 1957.

Paper analyzes simple idealized structures built up of flanges and shear carrying sheet. Both forces and displacements are taken as unknowns and are assumed to vary linearly between nodal points. Equations are easy to form for geometrically simple structures and can be solved on digital computer. Reviewer believes, however, that the consistent matrix formulation of structural analysis with either forces or displacements as unknowns developed in *Aircraft Engineering*, Feb. to May 1955, is preferable, being more accurate in and easier to apply to complex structures.

J. H. Argyris, England

3617. Catchpole, E. J., The optimum design of compression surfaces having unflanged integral stiffeners, *J. roy. aero. Soc.* **58,** 527, 765-768, Nov. 1954.

A method is developed enabling rapid determination of the optimum cross-sectional dimensions of compression surfaces having unflanged integral stiffeners, and consideration is given to the effects of practical limitations on the design. The theoretical efficiency of the optimum integral design is found to be only 85% of that of optimum Z-stringer design.

From author's summary

3618. Noton, B. R., The shear strength at elevated temperatures of an aluminum-alloy honeycomb core bonded to loading plates with two types of adhesive films, *Flygtekn. Försöksanst. Medd.* **72,** 35 pp., 1957.

Shear tests have been carried out at temperatures up to 100 C on a honeycomb core from the U.S.A. in 3S-H19 aluminum alloy. The density of the core was 87 kg/m^3 (5.4 lb/ft^3). The cell size was 9.5 mm (0.375 in.) and the foil thickness, 0.1 mm (0.004 in.)

The Redux 775 and the Bloomingdale FM-47 adhesive films have been investigated for bonding the core to the shear-transmitting plates.

At room temperature, tests were conducted on specimens with the bonded cell sides of the core located parallel and perpendicular to the applied shear force (longitudinal and transverse specimens, respectively). At elevated temperatures, only the variation in shear strength of the longitudinal specimens was studied.

In the room-temperature tests, the mean longitudinal shear strength of the core was approximately 22.0 kg/cm^2 and the transverse shear strength 12.6 kg/cm^2. At 70 C, the mean reduction in the longitudinal shear strength recorded at room temperature was only 7% for Redux 775 and 4% for FM-47. At 100 C, this reduction was 36 and 38%, respectively. Thus for the temperatures investigated, the results showed that there is only a small difference in the mean shear strengths of this core when bonded with Redux 775 and FM-47. Comparisons between these test results and results from other sources have been made.

From author's summary

3619. Kuenzi, E. W., and Setterholm, V. C., Mechanical properties of aluminum multiwave cores, *U. S. Dept. Agric. For. Prod. Lab. Rep.* no. 1855, 17 pp. + 2 tables + 9 figs., Sept. 1956.

This report presents the results of tests of commercially produced aluminum multiwave cores (Type I) for use in structural sandwich construction. Detailed descriptions of core materials and testing procedures are given. Analyses of experimental data include methods for predicting compressive strengths from basic material properties. Test results show that Type I multiwave cores, which are more easily formed to curvature than cores of honeycomb configuration, had strength and rigidity values comparable to those of cores of true honeycomb configuration of the

same density and foil alloy. Design values of core properties are presented both in tabular form and as stress-strain curves.

From authors' summary

3620. Hopkins, H. G., The theory of deformation of non-hardening rigid-plastic plates under transverse load, Deformation and flow of solids, Colloquium Madrid, Sept. 26–30, 1955, 176–183, Berlin, Springer Verlag, 1956.

Work on the limit analysis of circular plates under transverse loading is reviewed. As a first step in removing the restriction of the theory to cases with circular symmetry, the general field equations are set up, first in Cartesian coordinates and then in curvilinear coordinates, the moments and the middle surface curvature rates being considered as the generalized stresses and strain rates, respectively. Author remarks that methods of integration must be investigated before specific problems can be solved.

R. M. Haythornthwaite, USA

3621. Kachurin, V. K., Numerical methods for solving some problems in structural mechanics (in Russian), *Sb. Leningr. in-ta inzh. zh.-d. transporta* no. 146, 294–312, 1954; *Ref. Zh. Mekh.* 1956, Rev. 4742.

Numerical methods for the solution of two problems are presented: beams on an elastic foundation, and the calculation of the stability of bars. G. S. Glushkov, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

3622. Sirchis, A., Construction method of a shell-type roof structure in prestressed concrete consisting of precast elements (in Rumanian), *Indust. constr. Mater. constr.* **7**, 8, 461–469, 1956.

Roof covering a building 43.8 × 15.34 m (145 × 51 ft) consists of 10 barrel shells, spanning across the building with 14.32-m clearance, each barrel shell being assembled of 10 sections supported by 30 × 50-cm (12 × 20-in.) prestressed concrete girders. These girders carry also longitudinal barrel shell along the center line of the building resting on skylight walls. Thickness of shells is 3 cm (1⅛ in.). Prestressing methods were proposed by engineers St. Angelescu, E. Baiculesou, M. Halmagiu, and I. Finchelstein. Of special interest is the comparison with a typical reinforced-concrete roof that would require following amounts of materials per m^2 of roof structure (actual quantities in parentheses): steel, 60.9 kg (15.28); timber, 0.6 m^3 (0.09); concrete, 15.9 cm (11.2). J. J. Polivka, USA

3623. Streletskii, N. S., Problem of strength in the light of principles of calculation method for constructions according to the limiting states (in Russian), *Collection Tr. Mosk. inzh.-stroit. in-ta*, **8**, 34–41, 1954; *Ref. Zh. Mekh.* 1956, Rev. 3159.

Courtesy Reverativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

3624. Dimitrov, N., Effects of strain theory on prestressing (in German), *Publ. int. Assn. Bridge struct. Engng.* **16**, 85–100, 1956.

In structures in which prestressing is employed, the deformation of the concrete gives rise, according to theory, to additional second-order permanent moments. If the moments due to the prestressing are greater (less) than those resulting from the long-term loadings, an increasing (decreasing) prestressing effect, which depends on time, is obtained. The accurate determination of the creep strain m of the soil is of considerable importance from the point of view of the effect of the plastic sensitivity.

The deformation coefficient ν is taken as a criterion. For the purposes of practical application, the effect of the additional stresses can be considerable for $\nu < 25$.

From author's summary

3625. Jaeger, T., Basic elements of limit design (in German), *Bauingenieur* **31**, 8, 273–291, Aug. 1956.

3626. Eby, R. E., Developments in structural glued laminated construction, ASTM Second Pacific Area Nat. Meet., Sept. 17–21, 1956. Pap. 90.

Structural glued laminated construction, a development of the last 25 years, resulted in a 300-ft span arch-dome in Montana, a 247-ft span arch in Florida, a 250-ft span arch in Long Island, and 103-ft pressure-treated highway bridge girders in Manitoba. Each of these girders contains 12,000 fbm. Douglas fir and 503 lb waterproof glue, and weighs over 11 tons.

Reference is made to the know-how which is necessary to secure such accomplishments. E. G. Stern, USA

3627. Luxford, R. F., and Erickson, E. C. O., Rigidity and strength of houses built of plywood stressed-cover panels, ASTM Second Pacific Area Nat. Meet., Sept. 17–21, 1956. Pap. 114.

A framed stressed-skin 21 × 29-ft one-story prefabricated house with flat roof was tested as to its ability to resist high wind forces by applying loads through ¾-in. steel rods diagonally from bottom sill to opposite top sill of the house.

A load which amounted to approximately four times the 20-lb/sq ft wind pressure resulted in a permanent set from the diagonal distortion of only ⅛ in., which could not be noticed by visual observation. E. G. Stern, USA

3628. Cruciani, E., New centering for bridges, *Timber Technol.* **65**, 2211, 22–23, Jan. 1957.

Arched beams are formed by nonjointed laminations of thin boards or planks held together by closely spaced clamps. Spans up to 170 ft have been bridged with these units. By applying the same assembly principle to arched trusses, the centering for a 330-ft arched bridge was built in Northern Italy.

E. G. Stern, USA

3629. Kovacs, O., Distribution of loads on derrick bridges between different planes in the structure (in Hungarian), Gép **7**, 9, 333–338, Sept. 1955.

Truss bridges with head girders and auxiliary girders are statically multiply indeterminate space structures. The methods of calculation generally used reduce the construction usually to statically determinate girders. This leads to overdimensioning and wrong mass distribution. In this case the reserve of loading capacity is disproportioned in the different elements, some of them may be overloaded.

Author tries to approximate the real loading of the elements by taking account of the fact that the bridge structure is also submitted to torsion due to the loading. The center of torsion is determined by the assumption of the equal deflection of the auxiliary and head girders after transposition of loading forces. Once given the center, the deflecting forces loading the two vertical trusses and the moment of torsion acting on the bridge can be determined.

The loadings in each plane caused by the torsional moment are determined also by conditions of deformation and the loadings caused by deflection and torsion are superposed. The conditions of deformation used in the determination of torsional loadings are not verified correctly, but author refers to a series of measurements to be published in a subsequent article which, according to his opinion, will confirm his theory.

Some principles of construction drawn from the theory are given at the end of the paper.

The merit of the paper lays in pointing out a more approximate method of calculating the real loadings of crane bridges with auxiliary girders. Nevertheless, the theory of determination of the torsional loadings requires further detailed investigations.

G. Pattantyus, Hungary

3630. Balog, L., Grid bridge design, *Civ. Engng., N.Y.* **27,** 1, 40-45, Jan. 1957.

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 3557, 3558, 3586, 3592, 3594, 3609, 3806, 3845, 3851, 3853)

3631. Stowell, E. Z., A phenomenological relation between stress, strain rate, and temperature for metals at elevated temperatures, *NACA TN* 4000, 19 pp., May 1957.

A phenomenological relation between stress, strain rate, and temperature is suggested to account for the behavior of polycrystalline metals above the equicohesive temperature. The properties of the metal included in the relation are elasticity, linear thermal expansion, and viscosity. The relation may be integrated under various conditions to provide information on creep rates, creep rupture, stress-strain curves, and rapid-heating curves.

Some published and hitherto unpublished data for 7075-T6 aluminum alloy can be fitted only fairly satisfactorily by the relation. From author's summary by T. Broom, England

3632. Hoff, N. J., On primary creep, *J. Mech. Phys. Solids* **5,** 2, 150-151, Mar. 1957.

Primary creep under constant mean stress is explained, considering two different neighboring crystals which may be assumed to have same dimensions, elastic properties, and creep rate but different Norton constants in secondary creep. If their initial stress is equal, partition of stress will change with time and reach an asymptotic value. F. K. G. Odqvist, Sweden

3633. Durelli, A. J., and Riley, W. F., Use of creep to determine the sum of the principal stresses in two-dimensional problems, *Proc. Soc. exp. Stress Anal.* **14,** 2, 109-116, 1957.

For the separation of the two principal stresses use can be made of the circumstance that the change in thickness of the model in each point is proportional to the sum of these stresses in the point. Certain materials, such as Masblette and Catalin, exhibit the property of optical and mechanical creep under mechanical load; the change in thickness, however, stays proportional to the sum of the principal stresses at all moments, even during the relatively long recovery period after unloading. The latter phenomenon makes it possible to measure the changes in thickness of the model after removal of the load on a comparator. As the changes in thickness are appreciable, even with a model thickness of about 0.25 in., the accuracy obtainable is satisfactory, as is shown with an example of a circular ring loaded by two diametrical forces.

From an experimental point of view, the main advantage of the method lies in the fact that, with a suitable comparator, the measurements of the thickness in a sufficiently large number of points should be possible in a few minutes, so that much time can be saved. R. G. Boiten, Holland

3634. Ghaswala, S. K., Some aspects of the plastic design of aluminum structures, *Publ. int. Assn. Bridge struct. Engng.* **16,** 231-254, 1956.

The main survey of the present status of plasticity in the field of aluminum design covers topics on bending and torsion, inelastic instability and plate stability, compression, and frameworks.

From author's summary by R. Weck, England

3635. Olshak, V., and Litvinishin, G., The nonlinear phenomenon of liquid flow as a rheological simulator (in Russian), *Bull. Polsk. Akad. Nauk (IV)* **2,** 2, 71-76, 1954; *Ref. Zh. Mekh.* 1956, Rev. 3870.

To investigate the creeping of concrete and the relaxation of steel, which it has not been found possible to simulate by means of models formed of elastic and viscous elements, it is suggested to use a "hydraulic simulator" in the form of a pair of communicating vessels. One of these contains a piston, the force acting on which varies with the position of the piston. The area of the horizontal cross section of the second vessel varies with the height according to a particular law.

Simulation is based on the relationship between the distance from the bottom of the piston to a level $z_1(t)$ and the time t which, after contracting and integrating, has the following form:

$$z_1 = \frac{\beta}{\alpha} - \frac{\alpha}{4}\left(t \pm \frac{2\sqrt{\beta}}{\alpha}\right)^2$$

where α and β are constants.

Differing from the accepted Maxwell-Kelvin models which represent creep in the form of exponential curves, the present method enables the characteristics of the process to be defined by a representative function.

The phenomenon of chemical shrinkage can be simulated by using volatile liquids. Comparison of the characteristics of the suggested simulators with the behavior of solid steel gives satisfactory agreement. R. V. Torner, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

3636. Shorter, S. A., The elements of a unified theory of yarn structure and strength, *J. text. Inst. Trans.* **48,** 4, T99-T108, Apr. 1957.

The breaking of spun yarns under ordinary loading is treated theoretically. Results agree semiquantitatively with experimental results on cotton yarns by Gregory [title source, **41,** p. T30, 1950; **44,** p. T499, 1953]. The theory considers effect of twist on incidence of fiber slippage and breakage, and on the nonsimultaneity of fiber breaks. Thus it is more general than the theory of Sullivan [*J. appl. Phys.* **13,** p. 157, 1942], who considers slippage but implicitly assumes effective simultaneity of breaking, and that of Platt [*Text. Res. J.* **20,** p. 1, 1950], who, in treating only continuous-filament yarns, takes simultaneity of breaking into account, but is unable to make provision for slippage.

D. J. Montgomery, USA

3637. Marin, J., Theories of strength for combined stresses and nonisotropic materials, *J. aero. sci.* **24,** 4, 265-268, 274, Apr. 1957.

It is suggested how the distortional energy criterion of yield or failure can be modified for anisotropic materials. Author does not mention that this was first proposed in 1948 by reviewer, with even more generality and with an associated flow law [see Hill: "Mathematical theory of plasticity," chap. XII]. Author also proposes a modification for materials with different strengths in tension and compression; there is no reference to several similar criteria put forward by previous writers. R. Hill, England

3638. Crussard, C., Plateau, J., and Morillon, Y., Mechanism of fracture of metals (in French), Deformation and flow of solids, Colloquium Madrid, Sept. 26-30, 1955, 117-128. Berlin, Springer Verlag, 1956.

Paper discusses the initiation of fracture. In notched bending specimens, fracture starts at the surface (at the root of notch) or inside. In every case a permanently deformed zone is observed. The deformation patterns obtained by Fry's method suggest that the brittle fractures start in a domain where a plastically deformed zone touches an undeformed zone. Plotting impact-energy on log-normal probability paper gives for each of the two coexisting types of fracture a normal distribution of probability. Complementary tensile tests at -196° on mild steel show a strong scatter of elongation at fracture (from 1 to 22%), although the surfaces of fracture in all cases were crystalline. By plotting the elongation values on probability paper, one states different regions with

normal distribution, which are separated by zones of elongation with little probability. In specimens broken when a few flow lines appeared, the fracture starts on the boundary of a Lüders line. After a mean elongation but before necking, the origin of rupture is apparently a diminution of the cohesion owing to the deformation. H. Mussmann, Germany

3639. Rose, H. E., Gear failures of ball, tube and rod mills, *Engineer, Lond.* **203,** 5280, 522–524, Apr. 1957.

The breakdown of the gearing of ball, tube, and rod mills is discussed and it is suggested that the failures are due to fatigue arising from the surging of the charge in the mill; even though the surging is insufficient to be manifest by reason of noise or current surges sufficient to trip the circuit breakers protecting the driving motor. A criterion for surging in such mills is given and it is suggested that if the mills were operated within the limits set down, the frequency of such failures would be reduced and more economical designs might be adopted.

From author's summary

3640. Lin, T. H., Analysis of elastic and plastic strains of a face-centred cubic crystal, *J. Mech. Phys. Solids* **5,** 2, 143–149, Mar. 1957.

Tests with single crystals show that slip occurs along certain crystallographic directions. In a face-centered cubic crystal, three such slip directions in each of four planes result in twelve slip systems. Since a general strain is defined by six components, the assumption of volume constancy reduces the situation to five independents. To determine the five operative slip directions, the principles of minimum as well as virtual work have been applied. The author theorizes that, as the strain imposed upon a crystal rises, the shear strain resolved along the slip systems increases. When the critical shear stress along some one of the slip planes is reached, plastic slip takes place. Work-hardening increases the critical level in the other slip planes while that along the first is reduced by the amount of plastic slip. As the imposed strain continues to increase, slip begins along a second slip system and proceeds simultaneously with the first. This continues until all five slip systems are found. The author formulates this theory using tensor mathematics. Both the elastic and plastic strains in a face-centered cubic crystal are thus analyzed. J. P. Vidosic, USA

3641. Nash, W. A., and Hijab, W. A., On impact accompanied by fatigue, *Publ. int. Assn. Bridge struct. Engng.* **16,** 357–372, 1956.

A new concept of "fatigue equivalent acceleration" is introduced. For a given acceleration record, the f. e. a. is that acceleration level which will produce in one cycle an amount of fatigue damage equal to the cumulative damage produced by all the acceleration levels present in that record. If the structure is a single-degree-of-freedom variable frequency oscillator, a plot of the f. e. a. versus frequency of the oscillator is called a "generalized shock spectrum". Paper discusses possible uses of these concepts on the basis of Miner's cumulative damage theory. Y. C. Fung, USA

3642. Forsyth, P. J. E., Some observations on the nature of fatigue damage, *Phil. Mag.* (8) **2,** 16, 437–440, Apr. 1957.

3643. Viglione, J., Fatigue strength of bolts, *Prod. Engng.* **28,** 3, 203–205, Mar. 1957.

3644. Kemsley, D. S., Effects of cyclic stress and frequency on deformation markings in fatigued copper, *Aero. Res. Lab., Melbourne, Austral. Rep.* MET. 17, 16 pp. + 26 figs., Aug. 1956.

3645. Stussi, F., Fatigue stability and the experiments of August Wohler (in German), *Mitt. T.K.V.S.B.* no. 13, 47 pp. + 2 illus., 1955.

3646. Hartman, A., and Jacobs, F. A., The fatigue strength at fluctuating tension (R = 0.1) of Redux bended 75S-T Clad simple lap joints from -45° C to + 80° C, *Nat. LuchtLab. Amsterdam Rap.* M. 2016, 11 pp. + 7 tables + 6 figs., Aug. 1956.

Fatigue tests at fluctuating tension, R = 0.1, have been conducted on 75S-T Clad simple lap joints at –45, 20, 50 and 80C to determine the influence of the temperature on the fatigue strength of Redux-bonded joints. The adhesive was cured half an hour at 145 or at 160C. The results are: Low temperature (–45C) has a favorable influence on the fatigue strength. If the adhesive is cured half an hour at 160C, an increase in temperature from +20 to +50C does not have any influence on the fatigue strength. At 80C, joints cured at 145C have a low fatigue strength. At 80C the adhesive is unstable and continues to harden. This has a favorable influence on the properties at elevated temperature; the strength at room temperature is not impaired.

From authors' summary

3647. Boiten, R. G. Design and construction of machines with regard to fatigue (in Dutch), *Ingenieur* **68,** 31, 99–105, Aug. 1956.

The design of a dynamically loaded structure or component is complicated by the vast amount of information and recommendation in current literature. In a general way the various considerations of the designer are analyzed, and the pertinent data available are used. As a practical example, a theoretical and experimental investigation of a torsional leaf-spring combination for railroad cars is described. From author's summary

3648. Hartman, A., and Klaassen, W., The fatigue strength at fluctuating tension of single lap joints of Clad 24S-T and 75S-T aluminum alloy with 2 rows of 17S rivets, *Nat. LuchtLab. Amsterdam Rap.* M. 2011, 7 pp. + 4 appendixes + 3 tables + 14 figs., July 1956.

Results are presented of a fatigue investigation on 2 row riveted single lap joints of Clad 24S-T and 75S-T aluminum alloy at fluctuating tension and a mean stress in the net section of 9 kg/mm². The results show that a simple relation between the fatigue strength of 2 row riveted simple lap joints and the static strength of the joint or a simple parameter of the dimensions of the specimens like ratio of rivet pitch to rivet diameter does not exist. Probably the load transmitted by friction has an important influence, especially on the fatigue limit. The fatigue strength of 2 row simple lap joints of 24S-T alclad sheet was superior to the fatigue strength of 75S-T Clad specimens of identical dimensions.

From authors' summary

3649. Martin, J. W., and Smith, G. C., A preliminary study of the fatigue of metals in liquid metal environments, *Metallurgia, Manchr.* **54,** 325, 227–232, Nov. 1956.

The possible increasing use of liquid metal coolants emphasizes the importance of a knowledge of the fatigue properties of metals and alloys in contact with liquid metals. Authors present and discuss the results of fatigue tests at room temperature on amalgamated copper alloy, and at 300 C on mild steel and stainless steel in contact with liquid tin and liquid sodium, respectively.

From authors' summary

Material Test Techniques

(See Revs. 3638, 3660)

Mechanical Properties of Specific Materials

(See Revs. 3602, 3603, 3604, 3605, 3606, 3610, 3611, 3612, 3618, 3619, 3631, 3634, 3636, 3644, 3648, 3655, 3658, 3788, 3789, 3799, 3845, 3865)

Plasticity, Forming and Cutting

(See also Revs. 3553, 3639)

3650. Shaffer, B. W., An analysis of the orthogonal boring operation, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-67, 8 pp.

Removal of a chip from the inside of a circular cylinder is considered. Plastic flow occurs along a single cylindrical slip surface. This surface is determined by kinematic considerations and by limiting stress conditions in the chip adjacent to the cutting edge of the tool. Curves of ship thickness, machining force, and shear angle are presented and also the geometry of deformation of a grid on the workpiece. The approach of the theory in the limit to the previous planing solution is given. E. H. Lee, USA

3651. Broadbent, S. R., and Callcott, T. G., Coal breakage processes. Part II, A matrix representation of breakage, *J. Inst. Fuel* **29,** 191, 528–539, Dec. 1956.

Using matrix algebra, the effect upon particle size distributions of breakage processes and size classification is treated. Complex processes may be analyzed by simple arithmetical procedures when matrices are used. Breakage functions are discussed and used to set up a breakage matrix. A number π, used to define the proportion of particles broken, is determined by comparison with experiments.

Method is an interesting application of matrix algebra and appears to be a simple and powerful tool. Further development along the lines drawn up is to be expected and is indicated in paper.
B. Langefors, Sweden

3652. Broadbent, S. R., and Callcott, T. G., Coal breakage processes, Part I, A new analysis of coal breakage processes, *J. Inst. Fuel* **29,** 191, 524-528, Dec. 1956.

A survey of theoretical methods proposed is given. A new method is introduced, using vectors to describe particle size distributions and defining breakage process and selection by matrices. The meaning of matrices and rules for matrix arithmetic are given, making paper readable for those not familiar with this concept. Paper is to be followed by subsequent ones giving details and applications.

In an appendix, terminology and mathematical models to be used subsequently are presented. B. Langefors, Sweden

3653. Rosenberg, A. M., and Eremin, A. N., The influence of deformation rate on the stress in the process of metal cutting (in Russian), *Izv. Tomskogo politekh. in-ta* no. 75, 26–46, 1954; *Ref. Zh. Mekh.* 1956, Rev. 4865.

Results of experiments by the authors are presented. The process of cutting is examined, and theoretical considerations are given on the influence of different factors on the rate of deformation and its effect on stress conditions. It is maintained that in cutting the rate of deformation depends on the cutting speed, the character of the deformation diagram, the extent of deformation, and the thickness of the layer removed. The fundamental factor is the cutting speed, since this can vary within very wide limits. Authors assume that in the cutting process the rate of deformation varies only with variation of the cutting speed, and approximately proportionately to the latter.

All experiments were made with free cutting. Three metals were tested: a high-melting steel, a low-melting lead, and aluminum as intermediate between lead and steel in regard to melting temperature. The experimental results are plotted in graphs.

Experiments made with steel show that the cutting speed can influence the cutting force by changing the coefficient of friction and chip contraction, but that the cutting speed, as a quantity representing the rate of deformation, does not independently influence the cutting force and the tangential stress in cutting.

For comparison, the influence of the rate of deformation on torsion was determined for the same steel. It was found that the rate of deformation had no appreciable influence on the torsional moment, and consequently on the torsional stress. Thus the appearance of an influence of deformation rate in torsional tests on steel was found to be as insignificant as in the cutting experiments.

The experiments with lead showed that the cutting speed very considerably influences the stress. At low speed the stress does not depend on the degree of deformation and remains constant with appreciable variation of the relative shear. At higher speeds the stress grows with increasing degree of deformation, the more considerably, the higher the speed.

A comparison was made of the changes in stress during cutting, depending on the speed, with the changes in the process of compression. With increasing rate of deformation the compressive force, and hence the stress, increase very considerably. It has been determined that lead at room temperature shows no work-hardening under conditions of constant deformation rate, the stress remaining constant throughout the compression process. The influence of the rate of deformation on stress was found to be identical both in cutting and in compression.

The experiments with aluminum showed that the influence of cutting speed on cutting stress is less important than in the case of lead but more pronounced than in the case of steel.

No experiments were made on the determination of the influence of rate of deformation on stress in other forms of deformation of aluminum.

The fundamental conclusion to be drawn from this investigation is that the extent of the influence exerted by the rate of deformation on the stress condition in cutting depends on the melting point of the metal, and is exactly the same as in other forms of deformation. N. G. Kushelev, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

3654. Pawlowitz, K. R., Profile rotation turning—A new process for metal working(in German), *Technik und Betrieb* **8,** 10, p. 201, Oct. 1956.
Courtesy of European Technical Digests.

3655. Edwards, R. D., Stretch-forming of non-ferrous metals, *J. Inst. Metals* **84,** 199–209, 1955-56.

After a brief account of the theory of stretch-forming, machines and methods are described for stretch-forming aluminum-alloy sheets, extrusions, and sections for use mainly in the aircraft industry. Aspects dealt with include the limitations of the method, effects of heat treatment and differential work-hardening, type of stretch-forming and stretch-wrapping machines, and design of and materials for tools. Some examples of stretch-formed components are illustrated. From author's summary

3656. Kececioglu, D., Force components, chief geometry, and specific cutting energy in orthogonal and oblique machining of SAE 1015 steel, ASME Ann. Meet., New York, N. Y. Nov. 1956. Pap. 56-A-155, 15 pp. + 8 tables + 14 figs.

A three-component, SR-4 strain-gage, lathe dynamometer is described. Orthogonal and oblique cutting data obtained with this dynamometer, when dry, end-cutting SAE 1015, 118 bhn seamless-steel tubing are presented. Tools tipped with K3H grade, Kennametal sintered carbide and having normal rake angles varying from −10 to 37 deg and inclination angles varying from 0 to 36 deg were used to obtain the cutting data at speeds varying from 125 to 750 fpm and feeds varying from 0.004 to 0.012 ipr. The variation of the machining-force components, the cutting ratio, the thickness ratio and the specific cutting energy with the normal rake angle, the inclination angle, the cutting speed, and the tool feed are

analyzed in detail. The significance of each one of these factors to the metal-cutting process is expounded.

From author's summary

3657. Bhattasharyya, A., Analysis of metal cutting processes, *J. Instn. Engrs. India* **37**, 5, part 2, 495–509, Jan. 1957.

Paper gives a critical review of investigations on the action of cutting tools in machining operations and the effect of variables associated with it. Mathematical theories described here combined with the practical aspects of the problem give a reasonable opportunity to the machine tool engineer to specify machining conditions for better production. A survey is made of recent researches on machinability and metal cutting.

From author's summary

3658. Sabroff, A. M., Hubber, O. J., and Frost, P. D., Cold extrusion of unalloyed titanium, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56–A–88, 8 pp.

3659. Levin, E., Indentation pressure of a smooth circular punch, *Quart. appl Math.* **13**, 2, 133–137, July 1955.

3660. Samuels, L. E., and Mulhearn, T. O., An experimental investigation of the deformed zone associated with indentation hardness impressions, *J. Mech. Phys. Solids* **5**, 2, 125–134, Mar. 1957.

Using a metallographic method and specimens of 70 : 30 brass, experimental determinations have been made of the elastic-plastic and other low-strain boundaries of the deformed zone associated with indentation hardness impressions. Pyramidal impressions in specimens of semi-infinite and finite thickness, pyramidal impressions made close to the edge of the specimen, and ball impressions made under a range of indenting conditions have been investigated. The results suggest that indentation by the standard pyramidal indenter occurs in this particular material by a compression type of mechanism rather than by a cutting type of mechanism on which theoretical treatments of the indentation process have been based. The practical significance of the results is also discussed.

From authors' summary

3661. Perry, T. G., Bending and allied forming operations, *J. Inst. Metals* **84**, 211–216, 1955–56.

The metallurgical factors involved in plain bending, tube bending, flanging, and rolling are discussed. The concept of the strain-hardening exponent is used to provide empirical relationships for rolling-machine capacities, and for buckling criteria in bending.

From author's summary

3662. Sieggreen, H. G., Shell castings, typical examples of their applications, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56–A–94, 3 pp.

Hydraulics; Cavitation; Transport

(See also Revs. 3711, 3855, 3866)

3663. Iwasaki, T., On the discharge coefficients for crest spillways (in Japanese), *Trans. Japan Soc. civ. Engrs.* **43**, 2, 29–37, Feb. 1957.

The formula of discharge coefficient for crest spillways derived by H. Lauffer is modified to give the relation between the coefficients and ratios of heads to designed heads, constants of the formula being determined by the use of experimental values obtained by C. V. Davis, Creager, USBR, and the author himself, for standard crests, parabolic crests, and crests of other curves similar to the standard shape. T. Hayashi, Japan

3664. Mashkovich, L. A., Intake with curvilinear gate (in Russian), *Gidrotekh. i Melior.* **9**, 5, 33–38, 1957.

A vertical cylindrical gate is proposed in a trapezoidal channel in order to transform an hydraulic jump and to prevent a local scour. S. Kolupaila, USA

3665. Vaneiian, S. S., Application of submerged triangular weirs (in Russian), *Gidrotekh. i Melior.* **9**, 5, 39–42, 1957.

A diagram is developed of correction factors for submergence ratio and for direct reading of discharge over the weir. Correction is not necessary when submergence is less than 0.13 H.

S. Kolupaila, USA

3666. Levin, M., Flow of water following the rupture of a dam (in French), *Rev. gén. Hyd.* **18**, 72, 297–315, Nov./Dec. 1952.

3667. Burklakov, V. E., The hydraulic analysis of open parabolic channels with zero and reverse gradient (in Russian), *Torf. prom-st.* no. 1, 20–22, 1955; *Ref. Zh. Mekh.* 1956, Rev. 1476.

Author represents the hydraulic elements (effective cross section ω, wetted parameter (surface) χ) of parabolic channels by the monotonic function of the depth of flow h:

$$\omega = \omega(m)\, h^2, \qquad \chi = \chi(m)\, h$$

and thus transforms the known differential equation of the unsteady flow over a reverse gradient $-i$; after removing the series of the variables from under the integration sign and arbitrarily averaging them, the integrated part of the equation is reduced to the integral

$$\int \frac{d\xi}{1+\xi^5} = (\xi)$$

where

$$\xi = \eta \rho_1^{-0.2}, \quad \eta = \frac{h}{h_1}, \quad \rho_1 = \frac{\omega^2(m_1)\, R(m_1)\, C_1^2}{\omega^2(m)\, R(m)\, C^2}$$

In the above expressions m = cotangent of the angle to the horizontal of the tangent to the parabola at the water level; h_1 normal depth for flow volume Q and gradient i_1; R hydraulic radius.

To facilitate the calculations, author has compiled tables of the values of h_1, h_k, $R(m)$ and C, using the formula of N. N. Pavlovsky, with a roughness coefficient of $n = 0.025$.

In view of the averaging of values, the accuracy of the solution is lower than that of the forms of solution hitherto in use.

Courtesy of Referativnyi Zhurnal G. A. Dzhimsheli, USSR
Translation, courtesy Ministry of Supply, England

3668. Todd, D. K., Frequency analysis of streamflow data, *Proc. Amer. Soc. civ. Engrs.* **83**, HY 1 (*J. Hydr. Div.*), Pap. 1166, 18 pp., Feb. 1957.

3669. Proskuryakov, A. K., ed., Problems of hydrometry (in Russian), (Trans. State hydrological Institute, No. 47) Leningrad, Gidrometeoizdat, 98 pp., 1955; *Ref. Zh. Mekh.* 1956, Rev. 3022.
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

Incompressible Flow: Laminar; Viscous

(See also Revs. 3718, 3726, 3732, 3734, 3736, 3757, 3764, 3773, 3774, 3806, 3808, 3813, 3814, 3830, 3835, 3863, 3864, 3872)

3670. Christiansen, R. R., and Hixson, A. N., Breakup of a liquid jet in a denser liquid, *Indust. Engng. Chem.* **49**, 6, 1017–1024, June 1957.

Disruption of a liquid jet in extraction columns produces drops, creating extensive interfacial area. Rate of mass transfer between two liquid phases depends directly upon the area separating these

phases; therefore the correlation of mass transfer requires an accurate measure of interfacial area. Objective of present investigation is to develop theory for correlating drop sizes from breakup of liquid jets, and to determine the effects of some surface-active solutes on jet disruption. Previous work of Smith and Moss, 1917, and Tyler and Watkin, 1932, on correlations using Reynolds numbers and Weber numbers, and of Hayworth and Treybal, 1950, and Keith and Hixson, 1955, on flow rate and energy balance is surveyed. Theoretical analysis is based on Rayleigh, 1892 and 1899. Pure-solvent systems; effective interfacial tension; solutes of small molecular size; jet contraction were studied. It is found that growth of the axially symmetrical disturbance of jet causes disintegration. Nozzles were of 0.7 to 6.7-mm diam, 75 mm long. A large number of hydrocarbon solvents and solutes were used.

K. J. DeJuhasz, Germany

3671. Pattison, J. R., and Aldridge, J. D., Atomisation of water by spinning discs, *Engineer, Lond.* **203,** 5280, 514-519, Apr. 1957.

Characteristics of water sprays produced by spinning disks of various designs, and mechanism of droplet formation have been studied. Grooved disks with flat annuli prevent surface slip but do not reproduce the atomization processes occurring on plane disks. Vaned disks prevent slip but give fairly homogeneous sprays by the break up of small filaments at the disk edge in same way as plane disks. A simple formula relating drop diameter to liquid and disk parameters is discussed and shown to represent an over-simplification of the drop-formation process. A qualitative explanation is given for the drop spectra obtained. Several methods of dropsize measurement were investigated; finally, the method of capturing the drops on a microscope slide covered with a layer of magnesium oxide was adopted. The spectra of drop-size distribution is given in two representations: number of drops versus drop diameter, and volume of liquid versus drop diameter. Both the grooved disk and the vaned disk are illustrated.

K. J. De Juhasz, Germany

3672. Heidmann, M. F., Priem, R. J., and Humphrey, J. C., A study of sprays formed by two impinging jets, *NACA TN* 3835, 32 pp., Mar. 1957.

The spray formed by two impinging liquid jets was investigated over a jet velocity range of 5 to 100 fps to determine the characteristics of this method of atomization. At low velocities, the spray pattern was a smooth sheet completely surrounded by a liquid rim. As jet velocity increased, the rim separated at the downstream end. In this flow region an alternate spray pattern with a rippled sheet and periodic drops can occur. At higher jet velocities, a fully developed spray was produced which was characterized by waves of drops. The wave pattern was more distinct with high-viscosity fluids. The frequency of the waves in the fully developed spray increased with increasing injection velocity and decreasing impingement angle. Jet diameter and length before impingement had a negligible effect on the wave frequency. Characteristics of single jets were the same as determined by other investigators.

The liquid jets were formed with 2-in. lengths of precision-bore glass tubing of 0.025-, 0.040-, and 0.051- in. inside diam; they were oriented toward each other by a protractor device, and liquid was fed to them from two liquid containers pressurized from a common pressure gas cylinder. Variable parameters were: flow rate, impingement angle, jet diameter, and jet length before impingement. Both high-speed motion pictures (3000 frames per sec) and single-exposure microflash photographs of approximately 4-microsecond exposure were taken. The intermittent disintegration was observed and recorded by a photoelectric apparatus.

K. J. DeJuhasz, Germany

3673. Walton, W. H., and Prewett, W. C., The production of sprays and mists of uniform drop size by means of spinning disc type sprayers, *Proc. phys. Soc. Lond.* (*B*) **62,** 354, 341-350, June 1949.

Spray of almost uniform drop size is formed when liquid is fed onto the center of a rotating disk and centrifuged off the edge. This method of spraying has been studied over a wide range of variables; homogeneous clouds have been produced in the drop-size range of 0.015 to 3.0-mm diam. The size of spray drops is given approximately by $d = 3.8\ (T/D\rho)^{1/2}/\omega$ where d = drop diam, D disk diam, ω angular velocity of disk, T surface tension of liquid, ρ density of liquid. The spray thus formed also contains a proportion of fine satellite drops, but their smaller distance of travel from the disk permits them to be removed from the cloud when their presence in undesirable. Relatively coarse sprays are easily produced by a disk driven by an electric motor. Finer sprays require rotor speeds of 1000/sec or more, which can be obtained by means of an air-driven "top". Apparatus of this kind is described. Influence of rate of liquid feed, of disk speed, and of other variables on drop size have been investigated and are represented in charts.

K. J. De Juhasz, Germany

3674. Chernov, A. P., The effect of solid admixtures on the velocity of motion of a free dusty air jet, *NACA TM* 1430, 7 pp., Apr. 1957.

The presence of solid pulverized particles suspended in air in concentrations up to 1 kg particles per kg of air and velocities less than 30 m/sec has no significant effect on the aerodynamics of air jet. For velocities greater than 30 m/sec and concentrations other than 1, the effect can be calculated. This problem is treated from the aspect of friable materials being conveyed by means of air pressure, for drying, annealing, etc., of pulverized mass in suspension. Reference is made to Abramovich's equation which expresses the relationship between the velocity as a function of distance along the jet axis, and who found that the suspension obeys aerodynamic laws. Other authors found some influence, which however can be taken into consideration by means of a coefficient in the Abramovich equation.

K. J. DeJuhasz, Germany

3675. Vostrzhel, G. V., Analytical relationships in a free jet (in Russian), *Izv. Vses. n.-i. in-ta gidrotekh.* no. 52, 15-39, 1954; *Ref. Zh. Mekh.* 1956, Rev. 4550.

Assuming a velocity distribution in the cross section of the jet according to a probability curve, author determines the parameters of jets satisfying sufficiently the known experimental results.

The accepted velocity profile, as will be recollected, corresponds to the velocity distribution in a two-dimensional turbulent wake [B. Ya. Trubchikov: *Tr. CAHI,* 1938, no. 372] and in an axially symmetrical wake behind a body [G. L. Grodzovsky: *Prikl. Mat. Mekh.* **14,** no. 4, 437-440, 1950]; it is also known that the velocity profiles in a turbulent jet and a turbulent wake practically coincide [G. N. Abramovich: "Gas dynamics of jet propulsion units," Bureau of Modern Technics of the Moscow Aviation Industry, 195-201, 1947], which explains the agreement of the accepted velocity profile with the results of measurements, provided the experimental constant is suitably selected.

Courtesy Referativnyi Zhurnal G. L. Grodzovskii, USSR
Translation, courtesy Ministry of Supply, England

3676. Rasbash, D. J., and Stark, G. W. V., Control of the distribution of a spray projected to an area, *J. sci. Instrum.* **34,** 2, 75-76, Feb. 1957.

3677. Inlets for square conduits, *Houille blanche* **10,** 5, 775-781, Oct.-Nov. 1955.

Paper discusses transformation of a jet issuing from a square orifice and inversion of the transverse section about longitudinal axis of flow. Application is made to the design of transitions in the case of conduits of rectangular cross section. Detailed studies are presented of the various characteristics of the flow in the zone of transition between the initial section and the final

inverted section (direct and photographic observation, and simulation with electrical analogy). The advantages of this type of transition in comparison with transitions of customary shape are pointed out. From summary

3678. Khaskind, M. D., Unsteady motion of a solid in an accelerated stream of an infinite liquid (in Russian), *Prikl. Mat. Mekh.* **20**, 1, 120–123, Jan./Feb. 1956.

Using well-known concepts and properties [Lamb: "Hydrodynamics," chap. VI] in vectorial form, resultant force and moment on the body are formally determined, as functions of undisturbed stream and additive inertial terms.

G. Moretti, Argentina

3679. Uchida, S., The pulsating viscous flow superposed on the steady laminar motion of incompressible fluid in a circular pipe, *ZAMP* **7**, 5, 404–422, 1956.

An exact solution of the equations of motion is obtained. Many results are of practical interest concerning unsteady pipe-flow problems encountered in various hydraulic feeding systems, servo-systems, etc. Excess pressure work over is given. The excess work decreases with increasing frequency, neglecting compressibility effects. Pulsating pressure gradient on the mean does not create any excess mass flux over a period. Both the local and the sectional mean velocity oscillations lag behind the pressure gradient oscillations; this lag approaches 90° at infinite frequency. Maximum velocity is displaced from the axis and its radial position varies during the cycle. At large frequencies, the position of maximum local dissipation may be displaced from the wall during part of the cycle. S. I. Cheng, USA

3680. Avalishvili, L. E., Nonstationary boundary problem of Oseen, (in Russian) *Soobshch. Akad. Nauk Gruz. SSR*, **17**, 6, 489–494, 1956.

The three-dimensional interior or exterior problem of the flow of a viscous incompressible fluid bounded by a solid surface is treated for low Reynolds numbers by means of the Oseen approximation. It is assumed that the initial values of the potential throughout the fluid and values of the velocity on the boundary at all subsequent times are given. It is stated that the solution, which is not completely given, can be expressed in terms of Fourier-Mellin integrals. L. Landweber, USA

3681. Kostychev, G. I., Potential flow around a profile near a plane boundary (in Russian), *Trudi Kazansk. aviats. in-ta* **29**, 25–27, 1955; *Ref. Zh. Mekh.* 1956, Rev. 3477.

Courtesy Referativnyi Zhurnal A. I. Borisenko, USSR
Translation, courtesy Ministry of Supply, England

3682. Timman, R., The potential vector and its application to harmonic analysis of a three-dimensional flow, "Memoires sur la Mecanique des Fluides," *Publ. sci. tech. Min. Air, Paris*, 351–361, 1954.

3683. Seya, K., Numerical solution on characteristics of profiles with large camber in cascade of small pitch–chord ratio, *Sci. Rep. Res. Inst. Tohoku Univ. (B)* **7**, 69, 175–187, 1956.

A successive approximation method of solving Laplace's equation in the finite difference form under certain boundary conditions is used to determine the stream function for a uniform fluid flow past a cascade of airfoils with blade sections of large camber and thickness and small pitch-chord ratio. The degree of accuracy of the method is illustrated by particular examples.

The solution is applicable to gas and steam turbine operation.

E. E. Jones, England

3684. Schröder, H. J., Development of an approximation method for the calculation of three-dimensional cascade flow (in German), Jahrbuch der Wissenschaftlichen Gesellschaft fur Luftfahrt, 214–223, Braunschweig, Friedr. Vieweg & Sohn, 1955.

The interaction between cascades in turbomachines can be understood when a simplified problem is examined. A plane channel contains an infinitely dense plane grid with linear distribution of circulation. The flow passing through the grid undergoes a change of the velocity component parallel to the grid. However, the disturbance is small in comparison with the velocity of the parallel flow. Thus the angle β between the parallel flow and the grid plane is approximately constant. The flow is viscous and incompressible.

To this simplified model, the ideas of the Prandtl-Glauert theory of airfoils of finite span are applied. The components of induced velocity and static pressure are calculated. The results obtained for the plane channel are applied to an isolated axisymmetrical cascade and to the intake part of a multi-stage axial compressor. The effectiveness of the method is illustrated by a convenient example.

Reviewer observes that no assumptions are made as to the values of the angle β which is taken into account in the mathematical treatment. However, the expressions for the distances ρ_1 and ρ_2 in the formulas for the induced velocity are not correct when $\beta \neq \pi/2$; the coordinate η is then not the same in both expressions.

J. Beranek, Czechoslovakia

3685. Sobocinski, D. P., and Huntington, R. L., Current flow of air, gas-oil, and water in a horizontal pipe, ASME Ann. Meet. New York, N. Y., Nov. 1956. Pap, 56–A–60, 3 pp.

3686. Rapoport, L. A., Scaling laws for use in design and operation of water-oil flow models, *J. Petr. Technol.* **7**, 9, 143–150, Sept. 1955.

3687. Nonweiler, T., The air resistance of racing cyclists, *Coll. Aero. Cranfield Rep.* no. 106, 9 pp. + 4 figs., Oct. 1956.

Tests in a closed-section wind tunnel on three different cyclists mounted on a racing bicycle are described, and figures quoted for the recorded air resistance. Some comments are included on the implications of the results concerning the power output of racing cyclists. From author's summary

3688. Clark, R. N., Compensation of steady-state flow forces in spool-type hydraulic valves, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56–A–121, 5 pp.

Three heretofore unreported schemes for reducing the steady-state flow forces in spool-type hydraulic valves are described. Experimental data are presented which compare the steady-state flow-force characteristics of valves using each of these schemes to the characteristics of uncompensated valves.

From author's summary

Compressible Flow, Gas Dynamics

(See also Revs. 3717, 3735, 3747, 3756, 3759, 3765, 3766, 3767, 3768, 3769, 3808)

Book—3689. Liepmann, H. W., and Roshko, A., Elements of gas dynamics, New York, John Wiley & Sons, Inc., 1957, 439 pp. $11.00.

This book includes the fundamental material. A second one more advanced and specialized will follow. In 14 chapters it contains the following presentations: Concepts from thermodynamics; One-dimensional gasdynamics; One-dimensional wave motion; Waves in supersonic flow; Flow in ducts and wind tunnels;

Methods of measurement; The equations of frictionless flow; Small-perturbation theory; Bodies of revolution; Slender-body theory; The similarlity rules of high-speed flow; Transonic flow; The method of characteristics; Effects of viscosity and conductivity; Concepts from gaskinetics. The tendency is to enable the reader to understand the fundamental physical processes, to see what is relevant. That is attained by good simple sketches and short easy understandable formulas, avoiding intricate mathematical calculations. Therefore the book is especially suitable for the designer. It gives him the general principles and essentials not rapidly dated and leaves him the freedom to use it for design according to his own ideas. A. Betz, Germany

3690. Whitcomb, R. T., A study of the zero-lift drag-rise characteristics of wing-body combinations near the speed of sound, *NACA Rep.* 1273, 22 pp., 1956.

This report describes the original (1952) experimental proof of the sonic-area-rule concept of transonic drag rise and proposes the application of body indentations to reduction of transonic drag of wing-body configurations.

Correlated drag measurements (at zero lift), schlieren flow observations, and tunnel-wall Mach number distributions are given at Mach numbers from 0.85 to 1.10 for wing-body combinations having wings of aspect ratio 4, sweep back from 0° to 45°, and taper ratio of 0 and 0.6, and for their equivalent bodies of revolution. The results show that shock phenomena and drag rise increments are essentially the same for bodies having the same axial developments of cross-sectional areas normal to the airstream direction. Tests of wing-body combinations with bodies indented so that the axial developments of cross-sectional areas for the combinations were the same as for the original bodies alone have shown elimination or great reduction of transonic drag rise increments due to wings at zero lift. J. Lukasiewicz, Canada

3691. Berndt, S. B., On the drag of slender bodies at sonic speed, *Flygtekn. Försöksant. Medd.* 70, 17 pp., 1956.

Oswatitch's concept of equivalent slender bodies at transonic speeds (see Spreiter's excellent discussion in AMR **8**, Rev. 3821) is elaborated and used to assess changes in nonviscous drag due to changes of cross-sectional areas of these bodies. The difference in potential between two such bodies is governed by the linear Laplace equation in the cross plane, and author is led to drag laws known from the supersonic slender-body theory. For example, drag of bodies with rapid change of cross-sectional area A at the rear can be considerably reduced by spreading out A, say in a spanwise direction. M. V. Morkovin, USA

3692. Nocilla, S., Transonic flow around airfoils with a Mach number one of the undisturbed flow (in German), Jahrbuch der Wissenschaftlichen Gesellschaft für Luftfahrt, 186–192, Braunschweig, Friedr. Vieweg & Sohn, 1955.

Using the approximation of the adiabatic gas law given by Tomotika and Tamada, the mixed elliptic-hyperbolic type differential equation satisfied by the two-dimensional stream function is given and studied. The solution of this differential equation is given in terms of a class of functions which can be used to describe the transonic flow around symmetrical airfoils at zero angle of attack in a stream whose undisturbed velocity is sonic. Based on a theoretical argument using these functions, author concludes that a shock wave will always be present somewhere on the profile of an airfoil moving at sonic velocity. R. W. Detra, USA

3693. McDevitt, J. B., A correlation by means of transonic similarity rules of experimentally determined characteristics of a series of symmetrical and cambered wings of rectangular plan form, *NACA Rep.* 1253, 23 pp., 1955.

Transonic similarity rules are applied to the correlation of experimental data for a series of related rectangular wings of varying aspect ratio, thickness, and camber. The data correlation is presented in two parts: The first part presents the correlation for a series of 22 wings having symmetrical NACA 63A-series sections; the second part is concerned with a study of one type of camber by correlation of the data for a series of 18 cambered wings having NACA 63A2XX and 63A4XX sections.

It was found that the experimental data could be, for the most part, successfully correlated throughout the subsonic, transonic, and moderate supersonic regimes and that, by proper choice of parameters, the force and moment data could be presented in a concise manner effectively displaying the transonic characteristics of wings of both large and small aspect ratios. In many instances it was found possible to predict from the correlation studies an expected range of validity for the linearized or slender-body theories. It appears that, at the sonic speed, slender-body theory is adequate for rectangular wings of symmetrical profile if the product of the aspect ratio and the ¼ power of the thickness ratio is less than unity. From author's summary

3694. Lighthill, M. J., The wave drag at zero lift of slender delta wings and similar configurations, *J. fluid Mech.* **1**, 3, 337–348, Sept. 1956.

Ward's slender-body theory of supersonic flow is applied to bodies terminating in either a single trailing edge at right angles to the oncoming supersonic stream, or two trailing edges at right angles to one another as well as to the oncoming stream, or a cylindrical section with two or four identical fins equally spaced round it.

From the author's summary by S. B. Berndt, Sweden

3695. Mahony, J. J., Radial focussing in supersonic flows in ducts, *Aero. Res. Lab. Melbourne, Austral. Aerodynamics Note* 160,12 pp., Apr. 1957.

The problem of the radial focusing of small disturbances in a supersonic flow in a duct of circular cross section is considered. A linearized theory shows that the disturbance profile will be conserved but that the scale of the disturbance is subject to magnification as the axis is approached. However, it is known that if allowance is made for the variations in the speed of sound there may be a tendency for the disturbance to be smoothed out. A calculation of a special type of disturbance reveals that, for a large class of problems, this has no important effect on the production of large velocity fluctuations due to radial focusing.

From author's summary by H. Mirels, USA

3696. Chester, W., Supersonic flow past a bluff body with a detached shock. Part I, Two-dimensional body. Part II, Axisymmetrical body, *J. fluid Mech.* **1**, 4, 353–365, Oct. 1956; **1**, 5, 490–496, Nov. 1956.

A method of successive approximation is used to find a solution for inviscid flow about bluff bodies at high Mach numbers. With the stream function ψ and the distance from axis y as coordinates, the zero approximation is derived which corresponds to the Busemann hypersonic solution. By successive approximation a solution retaining terms of the order $(\delta + M^{-2})^2$ is then found where $\delta = (\gamma - 1)/(\gamma + 1)$. Results are calculated for a parabolic shock and body and for $\gamma = 1.4$. These results are shown with experimental data for flow over a circular cylinder so that comparison is valid strictly only for the immediate nose region. Within this limitation, agreement is good.

In part II, the same procedure is followed for axisymmetrical flow. On comparing the axisymmetric solution with the two-dimensional solution it was found that pressure distribution did not differ appreciably in the neighborhood of the nose.

A. J. Eggers, Jr., USA

3697. Holt, M., The method of characteristics for steady supersonic rotational flow in three dimension, *J. fluid Mech.* **1,** 4, 409–423, Oct. 1956.

The Coburn and Dolph method of characteristics for steady supersonic flow in three dimensions is extended to include shocks and entropy changes. The Ferri linearized method of characteristics for plane and conical flow is generalized to include perturbations of a given three-dimensional flow field. Two applications considered by Ferri, namely, perturbed plane flow in the case of a finite wing in any cross section in which the flow is essentially two-dimensional and perturbed axially symmetrical flow in the case of bodies of revolution at small angles of yaw and nonsymmetrical bodies, are subjected to the generalized method. The result is an important simplification of previous methods.

J. F. Lee, USA

3698. Drougge, G., and Larson, P.-O., Pressure measurements and flow investigation on delta wings at supersonic speed, *Flygtekn. Försöksanst. Medd.* 57, 32 pp., 1956.

Pressure distribution of two delta wings was obtained in an intermittent wind tunnel at $M = 1.5$ and various angles of attack. Both wings had identical planform with 70° sweep of the leading edge; one wing had a circular-arc profile with a sharp leading edge and maximum thickness at 50% of the local chord, the other a round-nose leading edge with maximum thickness at 35%c, both profiles were 6% thick.

Lift distribution and wave drag are analyzed on the basis of pressure distribution. Comparison with the conical flow theory indicates that the mean values obtained are in good agreement with theory and measurements for both wings at small angles of attack. There are, however, wide discrepancies in local pressure distribution, especially with sharp leading edge profiles. This is mainly due to the boundary-layer separation vortex pair originating at the nose of the wing.

Authors obtained pressure distribution above the wing surface within the zone of the separation-vortex-pair. Their measurements with a conical probe show clearly, for the sharp-edge wing, the direction of rotation of the main vortex and the pressure distribution of the main and the auxiliary small vortex attached to it. Successful measurements of static pressures within the separation zone by means of the conical probe indicate a new and interesting technique of great importance for the study of this type of flow.

J. E. de Krasinski, Argentina

3699. Vasavada, P. A., Application of hodograph method to obtain single symmetrical hyperbolic profiles and symmetrical hyperbolic profiles in cascade, Proceedings of the First Congress on Theoretical and Applied Mechanics, Nov. 1–2, 1955, pp. 213–218. Kharagpur, Indian Inst. of Technology.

A method of aerodynamic design has been given for a class of symmetrical single profiles and cascades.

The representation of the flow in the hodograph plane is obtained by a single doublet, while after suitable transformations the image of the airfoil contour is given by one branch of a hyperbola; the doublet is situated on the axis of this hyperbola and at the same side as the focus.

The research presented forms part of author's thesis "Hyperbolic aerofoils giving single profiles and cascades with similar pressure distribution," Faculty of Engineering, University of London, 1951.

E. M. de Jager, Holland

3700. Watkins, C. E., and Berman, J. H., On the kernel function of the integral equation relating lift and downwash distributions of oscillating wings in supersonic flow, *NACA Rep.* 1257, 18 pp., 1956.

See AMR 9, Rev. 1191.

3701. Fraser, R. P., Rowe, P. N., and Coulter, M. O., Efficiency of supersonic nozzles for rockets and some unusual designs, Instn. mech. Engrs., Prepr., 19 pp., July 1956.

Paper describes experimental work that has been carried out over a number of years to find an efficient rocket-nozzle shape that could be manufactured simply. Experiments have been conducted with nozzles generally of ½-in. diam throat discharging air to atmosphere from reservoir pressures in the region of 900 lb/sq in., and the thrust reaction and discharge rate have been measured. The air flow within the nozzle and the issuing jet have been examined photographically. The apparatus used and the experimental techniques are fully described.

The investigation has determined the best design for simple nozzles of conical divergence and found these to have a thrust efficiency of some 96%. Suitable entry radius and divergence angle are recommended, and the effects of machining errors, of obstructions in and near the nozzle, and of operating at incorrect pressure ratios have all been considered experimentally.

A number of unusual designs has been considered, including annular nozzles, a variable thrust-nozzle, and a nozzle designed to be mounted at the front of a rocket. These unconventional nozzles all have some special feature which makes them particularly suitable for certain requirements.

Paper gives data on all the nozzle-design details investigated, and an attempt has been made to relate the observed thrust-losses in conical nozzles to simple theory. Throughout the research and in presenting the results, the requirements and interests of the rocket-motor designer have been kept in view.

From authors' summary

3702. Graham, M. E., Lift to drag ratios of certain midwing monoplane configurations in supersonic flight, *Douglas Aircr. Co. Rep.* SM-22626, 28 pp., Oct. 1956.

The drag due to lift and the drag due to thickness of a certain midwing monoplane configuration in supersonic flight have been studied by R. M. Licher. In this report these drag values, together with an estimate of skin friction drag, are combined to obtain lift-to-drag ratios for flight at an optimum lift coefficient. In addition, the drag formulas are extended to include cases when the wing lies partly outside the fuselage Mach envelope.

The configuration is a Jones elliptic planform wing symmetrically mounted on a supersonically-area-ruled Sears-Haack fuselage. The fuselage may carry a lift distribution (but no net lift). Mach number, the intensity of the fuselage loading, and four independent geometric parameters (e.g., wing-aspect ratio, fuselage-fineness ratio, wing-volume to fuselage-volume ratio, and wing-chord to fuselage-length ratio) may be varied. Examples of numerical results are presented.

From author's summary

3703. Fettis, H. E., An approximate solution to supersonic conical flow, *J. aero. Sci.* **23,** 12, 1122–1123 (Readers' Forum), Dec. 1956.

3704. Freeman, N. C., On the theory of hypersonic flow past plane and axially symmetric bluff bodies, *J. fluid Mech.* **1,** 4, 366–387, Oct. 1956.

An analytical solution is obtained by a method of successive approximation for the small parameter $\epsilon = (\gamma - 1)/(\gamma + 1)$ and infinite free-stream Mach number. Body surface coordinates are used and the equations of motion are simplified by assuming boundary-layer-type flow between the body and shock wave. Neglecting all terms in ϵ gives as the zero approximation the Busemann hypersonic solution. In the basic solution, the shock-layer thickness (i.e., the distance between the body surface and the shock wave) was neglected. By reintroducing this distance into the solution, two successive perturbations were made giving results that had errors of the order of $\epsilon^{3/2}$ for axisymmetric flow and of $(\epsilon \log \epsilon)^2$ for two-di-

mensional flow. An outline is given adapting this method to gases with arbitrary thermodynamic properties.

A. J. Eggers, Jr., USA

3705. Talbot, L., Free molecular flow forces and heat transfer for an infinite circular cylinder at angle of attack, *J. aero. Sci.* **24,** 6, 458–459, June 1957.

Expressions for local stress and heat flux on a cylinder at any angle of attack are given in terms of specular reflection and accommodation coefficients. When these are constant, simple integrals result for total force and heat transfer. Graphs are given to show departure from values when flow is moved to cylinder. Author points out that integration in more general case is not difficult.

W. C. Griffith, USA

3706. Cole, J. D., Newtonian flow theory for slender bodies, *J. aero. Sci.* **24,** 6, 448–455, June 1957.

Pressure distributions for very high speed flow are discussed from the view point of combined Newtonian and hypersonic small-disturbance theory. A mathematical expansion is made in terms of the limiting ($M \to \infty$) density ratio. The latter is combined with the usual hypersonic similarity parameter and the resulting importance of a "Newtonian similarity parameter" is shown. Critical comparison is made with Van Dyke's theory.

J. Baron, USA

3707. Lees, L., and Kubota, T., Inviscid hypersonic flow over blunt-nosed slender bodies, *J. aero. Sci.* **24,** 3, 195–202, Mar. 1957.

At hypersonic speeds the drag/area of a blunt nose is much larger than the drag/area of a slender afterbody, and the energy contained in the flow field in a plane at right angles to the flight direction is nearly constant over a downstream distance many times greater than the characteristic nose dimension. The transverse flow field exhibits certain similarity properties directly analogous to the flow similarity behind an intense blast wave. A comparison with experiments on a flat plate with a blunt leading edge at $M_\infty = 13$ in helium shows that the shock-wave shape is predicted very accurately by this similarity analysis. The predicted surface pressure distribution is somewhat less satisfactory. Experimental results on a hemisphere cylinder obtained at $M_\infty = 7.7$ in air indicate that not only the shock-wave shape but also the surface pressures for this body are given very closely by the similarity theory, except near the hemisphere-cylinder junction. Energy considerations combined with a detailed study of the equations of motion show that flow similarity is also possible for a class of bodies of the form $r_b x^m$, provided that $m < m' \leqslant 1m' = \frac{2}{3}$ for a two-dimensional body, and equals $\frac{1}{2}$ for a body of revolution. By utilizing energy and drag considerations one finds that the inviscid surface pressures generated by a blunt nose are larger than the pressures induced by boundary-layer growth on an insulated surface over a distance from the nose which depends on the free stream Mach number and Reynolds number referred to the nose diameter. In free flight, viscous interaction effects are important over the forward portion of a blunt-nosed slender body only for relatively low Reynolds numbers. However, "far downstream" of the nose the inviscid over-pressure is small and viscous interaction phenomena will have to be taken into account.

From author's summary by H. P. Liepman, USA

Wave Motion Fluids

(See also Revs. 3784, 3867, 3869)

3708. Miche, R., Wave decay in shallow water (in French), *Houille blanche* no. 5, 726–745, Nov. 1956.

Author divides his work into three sections. In section I he considers the theory of boundary-velocity gradients of a wave in a viscous fluid, the approximate calculation of the boundary layer, and the wave decay when there is no turbulence. Section II is devoted to the examination of experimental results concerning the decay of laboratory-produced waves and their boundary zones. The present state of the problem is discussed in section III, and an indication is given of research work yet to be done. There is also an appendix in which the rate of decay of a wave in a viscous fluid of constant depth is calculated when the velocity behaves in a regular manner near the bottom.

G. Power, England

3709. Feldman, S., On the hydrodynamic stability of two viscous incompressible fluids in parallel uniform shearing motion, *J. fluid Mech.* **2,** 4, 343–370, June 1957.

A study is presented of the laminar stability of a liquid film flowing over a flat surface, dragged along by a high speed gas. This study can be considered as an extension of Lock's paper [AMR **8,** Rev. 1076] with the simplest possible model, i.e., linear velocity distribution in the liquid film and the adjacent gas current.

Starting from the Sommerfeld-Orr equation and its general solution for plane Couette flow, author analyzes the stability in remarkable detail. For various ratios of viscosities and densities of the two fluids, curves of neutral stability are evaluated, including the effect of surface tension and gravity.

Detailed calculations have been carried out for the case where these effects are negligible.

Author compares his findings with the experiments of others and states that discrepancies between theory and experiments are confined to the fact that the theoretical value of the critical Reynolds number is much larger than the experimental one, all other quantities being in agreement.

The paper is based on author's thesis.

H. J. Schoemaker, Holland

3710. Davidson, J. F., and Howkins, J. E., Wave induction on a vertical water film by an accelerating airstream, *Proc. roy. Soc. Lond.* (*A*) **240,** 1220, 29–41, Apr. 1957.

A vertical tower packed with spheres is used in industry to secure intimate contact between a falling liquid film and a rising stream of gas. A simple apparatus is used here to study the limiting rate of gas flow which halts the liquid flow by causing a large standing wave to form ("flooding point").

In the theoretical treatment, the gas is regarded as inviscid and incompressible, inertial forces being predominant. In the film, inertial forces are neglected, viscous drag being balanced against gravity and pressure gradient. (A derivation of the fundamental equation (3.3) would have been helpful.)

Agreement between theory and experiment is good. Reviewer feels that the laborious relaxation treatment could have been avoided by regarding the wave as a thin two-dimensional airfoil with a specified relation between its thickness and pressure gradient.

A. H. Armstrong, England

3711. Fedorov, E. P., Wave formation in water races (in Russian), *Gidrotekhn. str-vo* no. 3, 29–32, 1954; *Ref. Zh. Mekh.* 1956, Rev. 4426.

A number of results are presented of experimental investigations on this natural phenomenon. According to the author, it can be explained by the unsteadiness of the "hyper-turbulent" flow, when the flow velocity appreciably exceeds the surface wave velocity. The author concludes, however, that the theoretical steadiness conditions, as formulated by Businescu and Vedernikov, fail to agree with the experimental data, and presents some considerations regarding the explanation of the phenomenon.

Courtesy Referativnyi Zhurnal F. I. Frankl', USSR
Translation, courtesy Ministry of Supply, England

3712. Andronov, A. A., and Aronovich, G. V., The theory of the hydraulic ram (in Russian), *Inzbener. Sbornik, Akad. Nauk SSSR* **20,** 3–12, 1954; *Ref. Zb. Mekb.* 1956, Rev. 4454.

Paper begins with the construction of Bergeron-Schnieder shock diagrams for a hydraulic ram, using the simplifying assumptions of the absence of hydraulic resistance factors and inertia forces in the values. This construction is already known from the work of the present abstractor [*Tr. AN Gruz SSR, Energ. sektor* **3,** p. 67, 1945]. It is further demonstrated that the Königs-Lemaire diagrams used in the theory of iteration can be applied to the above problem of the hydraulic ram, being practically identical with the Bergeron diagrams. It is also demonstrated that if the duration of the "reflux" period does not exceed the shock ("ram") period the ultimate cycle is steady. M. A. Mostkov, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

Turbulence, Boundary Layer, etc.

(See also Revs. 3677, 3709, 3770, 3771, 3772, 3805, 3814, 3872, 3875, 3877)

3713. Wood, W. W., Boundary layers whose streamlines are closed, *J. fluid Mech.* **2,** 1, 77–87, Jan. 1957.

Author considers problems with a moving boundary, the speed in the boundary layer differing only slightly from that of the boundary. The velocity is found as a Fourier series in x (distance measured along the boundary), the coefficients being functions of ψ (the stream function), the inviscid flow having been also expressed in such a series. Certain conditions which must be satisfied by the inviscid flow are given, and these conditions render it possible to determine the inviscid motion, as affected by the viscous part of the motion.

Application is made to the flow inside a nearly circular ellipse, lined by a moving band, and to the flow past a rotating cylinder. Consideration is also given to the case of uniform inviscid flow with nonuniform motion of the boundary. Here it is found that the speed of the inviscid flow must be equal to the root-mean-square speed of the boundary.

Reviewer is in some doubt as to whether strictly a boundary layer exists under the condition that speeds vary only slightly everywhere, since such a layer can be defined as being a region where there is a high rate of shear, and this seems to be contradicted by the conditions given. J. C. Cooke, England

3714. Goldstein, S., Some developments of boundary layer theory in hydrodynamics, *Inst. Fluid Dynam. appl. Math., Univ. Maryland* Lecture Series no. 33, 27 pp., 1955.

A short review is presented of some of the mathematical difficulties attending the derivation of asymptotic expansions for laminar flows at large Reynolds numbers. Review is largely concerned with flow past a flat plate and contains an attempt to extend the domain of uniform validity of Alden's solution [AMR **1,** Rev. 1395] for the second approximation to the flow in the boundary layer. I. Proudman, England

3715. Vulis, L. A., and Kashkarov, V. P., Mixing of two homogeneous streams of a viscous fluid (in Russian), *Teploenergetika* **3,** 2, 41–46, Feb. 1956.

Paper deals with extensions of the problem concerning the boundary layer in the mixing region of two parallel flows. Here an attempt is made to generalize the problem for a class of antiparallel flows for both laminar and turbulent motions. Asymptotic theory of boundary layer is used. Existing solutions for the velocity distribution in parallel flows are generalized for antiparallel flows, and it is shown to what extent the solutions in both cases correspond to the method of superposition. Distribution of temperature is also investigated. J. Beranek, Czechoslovakia

3716. Smith, A. M. O., and Gamberoni, Nathalie, Transition, pressure gradient and stability theory, *Douglas Aircr. Co. Rep.* ES 26388, 59 pp., Aug. 1956.

Report presents a method of predicting transition on smooth plane and axially symmetric bodies that is based upon the use of Pretsch's theoretical rates of amplification of Tollmien-Schlichting waves. From correlation with experimental data on transition, it is found that a total amplification ratio of e^9 is undergone by the time transition is reached. This amplification ratio is then used as a parameter in predicting transition. The method represents a fairly good means of locating transition for engineering purposes. Agreement with Michel's method is good.

E. R. Van Driest, USA

3717. Gadd, G. E., An experimental investigation of heat transfer effects on boundary layer separation in supersonic flow, *J. fluid Mech.* **2,** 2, 105–122, Mar. 1957.

Wall-pressure distribution along a flat plate, whose temperature is varied from about -35 to $+75$ C, is measured in the separation region provoked either by an incident shock wave or by a spoiler placed on the flat plate, for both laminar and turbulent cases. Experiment is performed in a 2.6×1.5-in. blow-down tunnel at Mach number 3. Contrary to the theoretical predictions, the pressure distributions are found essentially unaltered by heating or cooling for laminar flow. Some explanation is given. For turbulent flow a slight effect is observed. It is concluded that, for a moderately heated or cooled plate, over-all pressure distributions associated with separation can be sufficiently estimated by using data for zero-heat transfer.

As the author indicates, more convincing evidence appears to be necessary. F. R. Hama, USA

3718. Strscheletzky, M., A contribution to the study of the hydrodynamic equilibrium of flows (in German), Voith Research and Design no. 2, 1–8, 1957.

The separation of the boundary layer from the wall surface is the result of a retardation of the boundary-layer flow and is due to the viscosity of the flowing liquid. Such separation is fundamentally different from the discontinuities, which are set up by the action of inertial forces (centrifugal forces) in flows and are dependent on the hydrodynamic equilibrium of the flowing liquid. Such discontinuities in the velocity field separate an "intact" flow from those zones which, while filled with liquid, are outside of the "intact" flow. Such zones are designated as zones of "inertial separation of flow" ("Tragheitsablosungen").

By means of the fundamental principles of mechanics the numerical study of the phenomena of inertial separation of flow is brought back to the analysis of the hydrodynamic equilibrium of a flowing liquid. The method, developed in this way, of the "least action" of flows allows calculation of the form and the extent of discontinuities that delimit the "intact" flow and correspond to their hydrodynamic equilibrium. This method also allows dealing with the problem of flows that, with given delimitations (walls), possess the hydrodynamic equilibrium and proceed without any phenomena of inertial separation of flow.

As examples for the results obtained so far in the computation of and the experimental checks on the hydodynamic equilibrium of flows are mentioned a) whirls in cylindrical pipes and diffusors; b) flows in bends.

The calculations and the test results clearly show that the hydrodynamic equilibrium of incompressible flowing fluids and the form and extent of the separation zones, which are set up as a result of the effect of inertial forces (centrifugal forces), depend on the velocity field of the flow and not on the pressure head.

From author's summary

3719. Coles, D., The law of the wake in the turbulent boundary layer, *J. fluid Mech.* **1,** 2, 191–226, July 1956.

By examining the bulk of existing data on turbulent boundary layers with various pressure gradients and comparing profiles on the basis of the logarithmic form of the law of the wall, and noting the universal agreement with the law near the wall and the characteristic departure from it away from the wall, author discovered an underlying wake-like character of the flow. He expresses the wake-like profile by a universal similarity law called the "law of the wake." A linear combination with the law of the wall is proposed as an over-all similarity law representing the complete profile. The law is found to fit observed profiles, and the wake hypothesis appears to be a useful concept. It moreover has been given a rational physical basis by the author. This apparently distinguishes the present method of generalizing a velocity law from the several methods proposed by others. Author suggests that yawed or three-dimensional flows may be represented by like universal functions in terms of vector quantities.

Reviewer believes that this work has gone far toward bringing much needed unification to the subject.

G. B. Schubauer, USA

3720. Shigemitsu, Y., Experimental studies on laminar sub-layer in turbulent boundary layer involving separation, *J. phys. Soc. Japan* **12,** 2, 183–190, Feb. 1957.

Measurements of mean velocity and longitudinal velocity fluctuations near the wall are reported for a turbulent boundary layer with and without pressure gradient. A positive pressure gradient has a destabilizing effect on the laminar sublayer. The Reynolds number characteristic of the edge of the sublayer falls from 165 (zero pressure gradient) to values as low as 60. The laminar sublayer persists until the boundary layer separates. R. Betchov, USA

3721. Corcos, G. M., and Liepmann, H. W., On the contribution of turbulent boundary layers to the noise inside a fuselage, *NACA TM* 1420, 43 pp., Dec. 1956.

An analysis of problem is formulated as a sequence of two linear couplings: the turbulent boundary-layer fluctuations excite the fuselage skin in lateral vibrations and the skin vibrations induce sound inside the fuselage. The techniques used are those required to determine the response of linear systems to random forcing functions of several variables. The results, strictly applicable only to the limiting cases of thin boundary layers, show that the sound pressure intensity is proportional to the square of the free-stream density, the square of cabin air density, and inversely proportional to the first power of the damping constant and to the second power of the plate density. For a flat spectrum the noise intensity depends on the fifth power of the velocity and the first power of the boundary-layer thickness. Consequently, the authors conclude, boundary-layer removal is not an economical means of decreasing cabin noise.

From authors' summary by A. K. Oppenheim, USA

3722. Stewart, R. W., Irrotational motion associated with free turbulent flows, *J. fluid Mech.* **1,** 6, 593–606, Dec. 1956.

Paper describes the results of a theoretical investigation of the irrotational flow that lies outside the sharp boundary that separates fluid in turbulent, rotational motion from fluid free from rotation. Particular attention has been paid to the effects of flow inhomogeneity in the direction of mean flow. The results of Phillip's earlier investigation, which assumed complete homogeneity, are substantially confirmed, but another mode of fluctuation with movement along the lines of mean flow is shown to be likely. For both motions, half the total kinetic energy of the fluctuations resides in the component normal to the mean boundary to the turbulent flow. The reasons for expecting the mean velocity outside the turbulent fluid to differ from the velocity at infinity are summarized and the difference calculated for particular boundary conditions.

Reviewer considers this paper to be valuable for its careful and complete discussion of the fluctuating motion outside a free turbulent flow and of its influence on the mean flow.

A. A. Townsend, England

3723. Townsend, A. A., The properties of equilibrium boundary layers, *J. fluid Mech.* **1,** 6, 561–573, Dec. 1956.

The recent work on equilibrium (i. e. self-preserving) turbulent boundary layers in adverse pressure gradients is compared with theoretical predictions based on current generalizations about the turbulent shear flow. Using only assumptions of similarity, it is possible to show that an equilibrium layer can exist only if the free-stream velocity varies as a power of distance downstream with an exponent greater than $-1/3$ and if the velocity defect from the free stream is small. Assuming further that the effective eddy viscosity is independent of distance from the wall over the outer part of the layer, most of the properties of equilibrium layers may by computed from the known behavior of layers in zero pressure gradient. The predicted values of skin friction and the predicted shape and magnitude of the mean velocity distribution are in fair agreement with the observations of Clauser. Finally, the modifications that are necessary if the velocity defect is not small are discussed briefly.

From author's summary by M. H. Bertram, USA

3724. Sen, N. R., Similarity in isotropic turbulence, Proceedings, First Congress on Theoretical and Applied Mechanics, Nov. 1955, 199–202, Kharagpur, Indian Inst. of Technology.

Attempting to give a greatly simplified analysis of the spectrum of isotropic turbulence during the early stage of decay, author neglects the viscosity relative to the "turbulent viscosity" in the Heisenberg spectral equation. The equation that remains has a similarity-type solution whose free constant can be adjusted to give agreement with some earlier theories. S. Corrsin, USA

3725. Burgers, J. M., An approximate equation for the correlation function connected with a non-linear problem, Proc. Eighth International Congress on Theoretical and Applied Mechanics, Istanbul, Turkey, Vol. II, Part IV-General Lectures and sectional addresses, Aug. 20–28, 1952, 89–103. Istanbul, Faculty of Science of the Univ. of Istanbul, 1955.

Paper discusses solutions of equation $\partial v/\partial t + v(\partial v/\partial y) = \nu(\partial^2 v/\partial y^2)$, assuming the term on the right-hand side to be small compared to the terms on the left-hand side. An equation is derived for the correlation function $R(\eta, t) = \langle v(y, t)v(y + \eta, t)\rangle$ where $\langle\rangle$ denotes an "ensemble average" assuming (1) that $R(\eta, t) = 0$ for $|\eta|$ sufficiently large, (2) that certain fourfold correlations can be expressed in terms of twofold correlations, and (3) that certain terms proportional to ν can be suitably modified. The resultant equation is briefly discussed. D. ter Haar, England

Aerodynamics of Flight; Wind Forces

(See also Revs. 3544, 3698, 3699, 3700, 3745, 3746, 3758, 3761, 3763)

Book—3726. Ower, E., and Nayler, J., High speed flight, New York, Philosophical Library, Inc., 1957, 227 pp. $10.00.

Book gives a self-contained presentation of the special problems of high-speed and supersonic flight. According to the authors' preface it will make the subject intelligible to the layman and interesting to experts in other branches of science and engineering.

In chap. I a survey is given on the main problems of high-speed flight, followed by a brief sketch of the historical development, and a discussion of future prospects. The next chapter explains the fundamentals of flight, i.e., aerodynamics and flight mechan-

ics. The essential problems of high-speed aerodynamics are described in chap. III. Then follows a chapter on engines, which treats mainly the turbojet engine. The ramjet and the rocket engine are also reviewed. "Structures and materials" is the heading of chap. V. Fatigue under repeated loading, buffeting and flutter, and stresses due to gusts are discussed here besides other problems of construction and materials. Several problems arising from the demands made on the human body are the subject of another chapter. Chapter VII is devoted to research and experiment in aerodynamics. Different types of wind tunnels are described and an account of experimental methods is given. Then follows a chapter on the aids to flight, in which stability and control—considered from a pilot's point of view—, powered control, boundary-layer control, vertical take-off and landing, as well as radio and radar aids are reviewed. The last chapter is dedicated to guided missiles.

The book is written in a very clear style and is endowed with many good illustrations. Mathematics have been vastly omitted. The most recent research results have been regarded. Some confusion has crept in with the curves for laminar and turbulent skin friction. On the whole the printing is excellent. The presentation will certainly fulfill its purpose. A bibliography has not been included. J. C. Rotta, Germany

3727. Von Karman, T., Faster, higher, hotter, *Interavia* **11,** 6, p. 407, June 1956.

Book—3728. Shapiro, J., Principles of helicopter engineering, New York, McGraw-Hill Book Co., Inc., 1956, xiv + 433 pp. $12.50.

Text is devoted to the technical aspects of helicopter engineering and covers all aspects of helicopter theory and design. It is unique in this respect and, considering the tremendous scope of the material treated, Mr. Shapiro is to be congratulated for providing a concise and clear discussion of the various subjects. Book is indeed a noteworthy contribution to the field of rotary wing aircraft and is highly recommended for student, practicing engineer, and users of helicopters. Due to its scope it should appeal to all. However, the reader should be cautious of numerous typographical errors and technical omissions. For example, on page 44, Ref. 1. 3. 2. 00 is mentioned in error, and on the same page the abscissa of Figure 1. 3. 2. 1 is indexed 10, 20, and 30 instead of 0.1, 0.2, and 0.3.

Included are chapters on (1) Rotating wings in steady flight; (2) Performance of helicopters; (3) Dynamics of the rotor; (4) Mechanics of helicopter flight; (5) Helicopter projects; and (6) Rotorcraft components and assemblies.

Excellent detailed drawings are presented together with useful design information on transmissions, rotor hubs, controls, landing gear, etc. L. Goland, USA

3729. Payne, P. R., Helicopter stability in hovering flight, *J. roy. aero. Soc.* **59,** 537, 635–640, Sept. 1955.

The purpose of this note is to draw attention to the powerful influence of Coriolis forces and flapping pin offset on helicopter stability. It is shown that, for a conventional rotor of small offset, the damping in pitch and the flight stability are greatly reduced by the absence of drag hinges, an effect which may explain the use of stabilizing bars on the successful helicopters which use this configuration. From author's summary

3730. Bruning, G., Dynamic stability of rotating wing aircraft (in German), *Z. Flugwiss.* **3,** 8, 241–260, Aug. 1955.

The object of the paper, which is based on unclassified literature, is to present the dynamic stability of rotating wing aircraft from a universal point of view. Following the theory of stability of airplanes, Hohenemser's theories for hovering and for forward flight are given in detail. Further development of the theories is indicated by the numerous suggestions contained mainly in American and British papers. The possibilities for making rotating wing aircraft stable are discussed.

From author's summary

3731. Automatic pilots for helicopters: I. Collomosse, H., Theoretical considerations; II. Curties, M. C., Flight development, *J. Helicop. Assn.* **11,** 2, 45–66, Apr. 1957.

3732. Helmbold, H. B., Theory of the finite-span blowing wing, *J. aero. Sci.* **24,** 5, 339–344, 370, May 1957.

The essential features of two-dimensional flow around a blowing wing are briefly outlined. The flow around the finite-span blowing wing is investigated under the simplifying assumption of undisturbed static pressure at infinity downstream. The effects of finite span are induced drag, and losses of jet thrust and jet-induced lift. The induced drag results from circulation around the wing and jet sheet, the loss of jet thrust from final jet deflection, and the loss of jet-induced lift from loss of jet-sheet curvature. The forces on the finite-span jet wing are functions of the induced angle which is determined either graphically from a sixth-degree equation or by a second-order approximation for moderate induced angles. The jet coefficients are finally represented as functions of jet-power coefficient and jet-sheet thickness ratio.

From author's summary by G. B. Schubauer, USA

3733. Spahr, J. R., Theoretical investigation of the effects of configuration changes on the center-of-pressure shift of a body-wing-tail combination due to angle of attack and Mach number at transonic and supersonic speeds, *NACA TN* 3966, 43 pp., May 1957.

Linearized theory is used to estimate the effect of varying various geometrical parameters on center-of-pressure shift. Shift due to increase in angle of attack is influenced primarily by ratio of wing semi-span to tail semi-span. Shift due to Mach number increase is influenced by same parameters affecting ratio of lift on wing to lift on tail. Total shift in transonic and supersonic range can only be controlled in a limited manner since the critical parameters have opposite effects in the two ranges.

M. Holt, USA

3734. Eppler, R., Direct calculation of airfoil profiles from pressure distribution (in German), *Ing.-Arch.* **25,** 1, 32–57, 1957.

Solution of the inverse problem of determining the two-dimensional airfoil profile that corresponds to a prescribed incompressible velocity distribution is provided by a series development that is generally more satisfactory for numerical evaluation than those previously used. The new series expansion utilizes the logarithmic as well as the trigonometric functions.

Numerical solutions are presented for two-dimensional laminar flow profiles having a prescribed favorable pressure gradient over their forward position. E. V. Laitone, USA

3735. Legendre, R., Calculation of a cascade of blades for a given distribution of the subsonic Mach number as a function of the potential (in French), *Rech. aéro.* no. 47, 3–9, Sept.-Oct. 1955.

Legendre uses his previous results ["Ecoulement isentropique d' un fluide compressible," *C.R. Acad. Sci. Paris* no. 21, 9, 1953] to express the flow of a compressible fluid along a cascade of blades in terms of functions depending upon Mach number. The potential and stream functions are chosen to be independent variables. From the structure of the method it is convenient to assume the distribution of Mach number (or of velocity) along a blade as given function of potential. The problem so defined reduces to two successive integrations. The first furnishes the velocity field as function of the potential, the second defines the flow field and, in particular, the form of the blade profile. Extensive use of

elliptic functions, in particular fast convergent Theta elliptic functions, is recommended. This is an interesting kind of inverse method: one seeks the form of the blade for the given velocity distribution. Flow along a single airfoil can be easily calculated by assuming that the distance between the blades approaches infinity. M. Z. Krzywoblocki, USA

3736. Charwat, A. F., Experiment on the variation of airfoil properties with Reynolds number, *J. aero. Sci.* **24,** 5, 386–388, May 1957.

3737. Helmbold, H. B., Limitations of circulation lift, *J. aero. Sci.* **24,** 3, 237–238 (Readers' Forum), Mar. 1957.

3738. Moller, E., and Trienes, H., Investigation of the neutral points of wing-fuselage combinations (in German), *Z. Flugwiss.* **1,** 1, 2–8, June 1953.

For a wing-fuselage combination, the aerodynamic center is forward relative to that of the wing alone. The destabilizing shift of the aerodynamic center depends largely on the position of the wing relative to the fuselage and also on the ratio of the size of the fuselage to that of the wing. Experiments on the two effects are presented. A comparison of experimental data with theoretical results obtained by H. Multhopp shows satisfactory agreement.

From authors' summary

3739. Gorczycki, E., Dynamic considerations relating to the behavior of inertial space-stabilized platforms, *J. aero. Sci.* **24,** 2, 130–138, Feb. 1957.

This paper presents a derivation of the dynamic equations of an inertial space-stabilized platform, taking into account the presence of arbitrary housing disturbance due to airframe motion at an isolated point in inertial space. There is also a short discussion of the stabilization of the platform by use of integrating gyros. No experimental results or detailed discussion are given beyond the derivation of Newton's equations.

R. E. Kalman, USA

3740. Coward, K. S., VTOL fixed-wing aircraft, *Aero. Engng. Rev.* **16,** 1, 35–39, Jan. 1957.

The spectrum of types includes tail sitters, ducted propellers, tilt wing, tilt engine, and deflected air stream. Basic physical considerations are discussed regarding development of static thrust, hovering lifting ability, etc.

From author's summary

3741. Weber, J., and Lawford, J. A., The reflection effect of fences at low speeds, *Aero. Res. Counc. Lond. Rep. Mem.* no. 2977, 14 pp., 1956.

Note considers the effect on the flow over a swept wing, of vertical plates of small height—commonly called "fences." It is shown, as might be expected, that the nature of this effect is that of a partial-reflection plate. The effect of this partial reflection on the pressure distribution over the wing on either side of the fence has been investigated theoretically and by means of pressure measurements at low speeds on an untapered 45-deg sweptback wing.

An earlier physical explanation of the flow changes caused by fences has been substantiated, and the proportion of full reflection effect has been determined experimentally for various shapes of fence. Methods are described for calculating the changes in pressures distribution, chordwise loading and spanwise loading.

The effect of a fence in obstructing boundary-layer outflow on sweptback wings of large aspect ratio has not been considered.

From authors' summary

Aeroelasticity (Flutter, Divergence, etc.)

(See also 3551, 3762, 3871, 3874)

3742. Garrick, I. E., Aerodynamic theory and its application to flutter, NACA, 26 pp. + 19 figs., Apr. 1956.

A brief but interesting comparative survey of the present-day aerodynamic theory of flutter is given, including sections on flutter concepts, aerodynamic concepts, and on applications. A number of graphs are presented in which significant comparison of various aerodynamic theories is made. Author concludes with the statement that the "accuracy of a flutter analysis is an elusive quantity and the theory must be supplemented by many experimental methods when calculated margins are small."

The tenor of the paper is professional, yet it is easily understandable. Reviewer recommends it not only to the initiate but also to the nonspecialist interested in gaining an appreciation of the status of the field. W. Targoff, USA

3743. Broadbent, E. G., Ill-conditioned flutter equations and their improvement for simulator use, *Aero. Res. Counc. Lond. curr. Pap.* no. 298, 17 pp. + 9 figs., 1956.

If simple arbitrary modes of the form n^a are used as coordinates in a wing flutter calculation, the equations are ill-conditioned and cannot be solved satisfactorily on a simulator. This ill-conditioning can be avoided by transforming the flutter matrix so as to reduce the inertia couplings between like modes to zero. This transformation is described with numerical examples, and some observations are made on the general problem of choice of coordinates in a flutter calculation.

From author's summary by M. V. Barton, USA

3744. Bosschaart, A. C. A., and Van de Vooren, A. I., Investigation of the effect of an improved strip theory for swept wings on the flutter speed, *Nat. LuchtLab. Amsterdam NLL-TN* F. 168, 11 pp. + 6 figs.

Diagrams of the nondimensional flutter speed as a function of the natural frequency ratio between wing bending and torsion are presented, showing the results obtained from calculations based on an improved strip theory derived by van de Vooren and Eckhaus for swept wings. The calculations have been performed for bending-torsion flutter of two types of wings with 45° sweepback. For the first type, which has a constant chord along the span, aspects ratios of 4 and 8 were considered, while the other type has a taper ratio 1/3 and an aspect ratio of 4. Bending-torsion-aileron flutter calculation has been performed for the tapered wing fitted with a statically balanced aileron over the outer half of the span. The results of the bending-torsion flutter calculations have been compared with the results obtained from the theory of Barmby, Cunningham and Garrick.

From authors' summary by M. V. Barton, USA

3745. Wilts, C. H., Incompressible flutter characteristics of representative aircraft wings, *NACA TN* 3780, 121 pp., Apr. 1957.

The present report gives the results of a detailed study of the flutter characteristics of four representative aircraft wings. This study was made using the electric analog computer at the California Institute of Technology. During the course of this investigation eight important parameters of each wing were varied and, in addition, the effects of mass, inertia, pitching spring, and location of a concentrated mass were investigated for all four wings and several sweepback angles.

The introduction of this report discusses in general terms the flutter characteristics of airplanes. The second section contains a discussion of the electric-analog principles that made a study of this magnitude feasible. The third section contains a discussion of the aerodynamic and structural approximations made for

simplifying the flutter analysis of a wing. The fourth section gives information relating to the errors introduced by the finite-difference approximations to continuous aeroelastic systems. In addition, data are given pertaining to the flutter characteristics of a swept-wing wind-tunnel model and the results of computations based on two assumptions regarding aerodynamic forces on a swept wing. The fifth section lists all pertinent data relating to the four representative aircraft wings and the sixth section contains the computed flutter characteristics of the four wings.

From author's summary

3746. Hedgepeth, J. M., Recent research on the determination of natural modes and frequencies of aircraft wing structures, NACA, Presented to Structures and Materials Panel of AGARD, 21 pp. + 13 figs., Apr. 1956.

The results of some recent theoretical and experimental studies of the vibrations of aircraft wing structures are summarized and discussed.

Assessment is made of the importance of various effects not usually included in the elementary theories of bending and torsion of box beams, such as transverse shear flexibility, shear lag, restraint of warping, longitudinal (rotary) inertia, and cross-sectional deformability. The substitute stringer method of incorporating the effects of shear lag into the analysis of box-beam vibration is outlined. Natural frequencies obtained experimentally from resonance tests of box-beam specimens are presented and compared with the results of theoretical calculations, and it is shown that good agreement, particularly for the higher modes, requires the inclusion of secondary effects in the analysis.

Two recently developed methods of analysis of low-aspect-ratio wings are described. Frequencies and modes calculated by these two methods are compared with those obtained experimentally for a large scale built-up delta-wing specimen. Frequency disparities are noted and sources of error are discussed.

From author's summary

3747. Dryden, H. L., and Duberg, J. E., Aeroelastic effects of aerodynamic heating, *AGARD Publications* AG20/P10, 102–107, June 1955.

It appears that the design of aircraft to withstand aeroelastic difficulties at high supersonic speeds will of necessity require the consideration of the effect of aerodynamic heating. Among the various aeroelastic consequences of aerodynamic heating, the reduction of over-all stiffness through the action of thermal stress is the most novel and may well turn out to be the most serious. An appreciation of this phenomenon must become part of the working equipment of the modern aeroelastician.

From authors' summary

3748. Hedgepeth, J. M., and Waner, P. G., Jr., Analysis of static aeroelastic behavior of low-aspect-ratio rectangular wings, *NACA TN* 3958, 21 pp., Apr. 1957.

Paper studies the influence of chordwise deformation on divergence of uniform plate wing with chordwise stiffening. Spanwise deformation is assumed parabolic and principle of stationary potential energy is used to derive differential equation for chordwise variation. "Slender-body theory" is used to compute induced aerodynamic forces and so set up equations for divergence. Exact results are obtained and compared with those using polynomial approximations to chordwise deflections. A "cubic" approximation gives good accuracy for practical configurations.

W. S. Hemp, England

3749. Wickens, A. H., A note on steady-state aeroelasticity, *J. aero. Sci.* **24,** 5, 383–384, May 1957.

Expressions are given for the aerodynamic loads on aircraft in terms of generalized displacements and modal shape functions, Matrix notation is used. Effects of flexibility on static stability and control are very briefly discussed in relation to control reversal and divergence. A scheme of calculation is suggested which requires the inversion of a large order matrix. Author states that satisfactory accuracy is obtained provided a reasonable choice of modal functions is made.

W. P. Jones, England

Propellers, Fans, Turbines, Pumps, etc.

(See Revs. 3551, 3552, 3571, 3683, 3699, 3783, 3836, 3849)

Flow and Flight Test Techniques

(See also Revs. 3665, 3698, 3720, 3930)

3750. Powell, H. N., and Browne, W. G., Use of coiled capillaries in a convenient laboratory flowmeter, *Rev. sci. Instrum.* **28,** 2, 138–141, Feb. 1957.

With coiled capillaries, the basic simplicity of the Hagen-Poiseuille flow equation can be retained at flow rates which are not achievable with straight capillaries. This fact lends itself to the design of flow metering systems (for liquids or gases) which appear to be intrinsically more reliable and accurate than many other types of systems, and which require only commonly available laboratory apparatus. One such metering system for gases is briefly described.

From authors' summary

3751. Cawley, W. A., and Woods, J. W., An improved dilution method for flow measurements, *Proc. Amer. Soc. civ. Engrs.* **82,** *SA 5 (J. san. Engng. Div.), Pap. 1084, 4 pp., Oct.* 1956.

A procedure for measuring the flow in sewers containing industrial wastes by a manganese dilution method is outlined. An inexpensive technical grade of manganous sulphate was injected into the sewers and the degree of dilution determined quantitatively by flame spectrophotometric analysis. It is felt that this approach provides an accurate and relatively simple method for use with industrial wastes.

From authors' summary

3752. Winternitz, F. A. L., Probe measurements in three-dimensional flow, *Aircr. Engng.* **28,** 330, 273–278, Aug. 1956.

A survey is made of the instruments and methods used to measure total and static pressure and direction in three-dimensional flow. Comparative tests in a towing tank of two designs of five-orifice pitot-type probe showed the advantage, within a limited range of flow inclination, of the instrument with independent static pressure orifices. Speed and angle-of-flow characteristics are given for these two probes, which differ in the shape of head.

From author's summary

3753. Cox, W. J. G., Development of an air mass-flow rate meter, *Aero. Res. Counc. Lond. curr. Pap.* 230, 31 pp. + 19 figs., 1956.

The development of an air-mass flow-rate meter to cover a very wide range is described which, essentially an analog computer, gives a two-sweep pointer direct presentation of air mass flow rate, independent of pressure, temperature, and velocity changes within the range of the instrument. The pointers are driven by a servo system which is error-actuated from the computing bridge network, secondary feedback being employed to maintain stability with a saturated angular output rate of approximately 33°/sec. Specifications and performance figures are given for the individual transducer elements and the complete instrument; error estimations are made; and the servo stability is discussed.

From author's summary

3754. De Smedt, J., and De Bock, A., Didactical absolute viscosimeter, *Amer. J. Phys.* **25,** 3, 152–154, Mar. 1957.

A didactical apparatus for the absolute measurement of small coefficients of viscosity (1 centipoise) with an accuracy of 1% is presented. A W-shaped piece rotates about a vertical axis at a variable distance from the walls of an identically shaped vessel, containing the liquid sample. A wire wound on a drum attached to the axis, carries a mass, which accelerates the rotor when falling through a distance H in the time interval T. When completely unrolled the wire is rewound on the drum and the mass is lifted up to a smaller height H' in a shorter time T'. The determination of both distances and time intervals permits calculation of the coefficient of viscosity. From authors' summary

3755. Weeda, W., The practical performance of some flow measurements by means of radioactive materials (in Dutch), *Ingenieur* **69,** 9, 23–30, Mar. 1957.

Three measurements are described: The measurement of a volume rate in a water curcuit of about 450 cu m/h is described. About 10 mc of Na 24 in a volume of 30 liters was added in a continuous stream. Rate measurements were accomplished (a) by determination of the time taken by the front and back of the radioactive "cylinder" moving in the pipeline in flowing from one fixed point to the other; (b) by taking samples from the injection liquid and from the radioactive liquid in the circuit; the ratios of the specific activities of these samples, together with the injection rate, give the volume rate in the circuit.

The accuracy of both methods is in the order of several per cent.

Measurement is made of the retention time in a pond (surface area about 10,000 sq m, depth 2 m). About 100 mc Na 24 was used; detection was carried out by means of geiger tubes.

The continuous measurement of the density of a suspension flowing through a pipeline is done by means of the absorption of a beam of gamma rays of Ir 192 sent diametrically through the cross section of the pipeline. Here also the detector is a geiger tube.

From author's summary

3756. Centolanzi, F. J., Characteristics of a 40° cone for measuring Mach number, total pressure, and flow angles at supersonic speeds, *NACA TN* 3967, 36 pp., May 1957.

Paper gives detailed calibration results for cones with four equally spaced static pressure holes and one total pressure hole at the apex, at Mach numbers 1.72, 1.95, and 2.46 and angles of yaw up to 26°. Results at two Reynolds numbers, 3.1×10^6/ft and 5.4×10^6/ft, were identical. Uncertainties were ± 1.0% in Mach number and ± 0.25° in flow angle. A detailed numerical example illustrates the use of the calibration graphs.

N. H. Johannesen, England

3757. Sams, C. E. R., Simple device for metering flow of liquids in pipes, *J. Instn. Water Engrs.* **10,** 202–211, May 1956.

3758. Hill, J. A. F., Baron, J. R., Schindel, L. H., and Markham, J. R., Mach number measurements in high-speed wind tunnels, *AGARD Publications* no. 22, 113 pp., Oct. 1956.

Measurements of subsonic and supersonic Mach numbers in air are discussed from the point of view of calibration measurements of an empty wind tunnel, of measurements of local Mach numbers at points in the flow field around a model, and of simulating free-flight Mach number in the presence of wind-tunnel wall interference. Errors in deducing Mach number from particular measurements are discussed and certain measuring procedures recommended. The most emphasis is placed on methods involving measurement of pressures.

From authors' summary by H. A. Stine, USA

3759. Laurmann, J. A., and Lukasiewicz, J., Development of a transonic slotted working section in the NAE 30-inch × 16-inch wind tunnel, *Nat. aero. Establ. Canad.* LR-178, 16 pp. + 36 figs., Aug. 1956.

Tests have been conducted in the 30-in. high-speed wind tunnel of the N.A.E. to develop a slotted working section free of solid blockage interference. Several designs have been tried and a final configuration obtained which gives reasonable flow uniformity (a maximum variation in Mach number of ± 0.01) in the working section up to a Mach number of 1.08. Transonic operation of the tunnel without choking is possible with half models of up to 2-½% blockage. Tunnel-wall interference was found to be negligible up to sonic velocities with 1% blockage models, and up to a Mach number of 0.95 with a 2-½% blockage model. There were no large interference effects for any of the models throughout the complete speed range tested (free-stream Mach numbers from 0.55 to 1.1).

From authors' summary by G. J. Nothwang, USA

3760. Rogers, E. W. E., Berry, C. J., and Cash, R. F., Tests at high subsonic speeds on a 10 per cent thick pressure-plotting aerofoil of RAE 104 section, *Aero. Res. Counc. Lond. Rep. Mem.* no. 2863, 49 pp., 1956.

3761. Asaka, S., and Oshima, K., Wind-tunnel experiments on the wake behind a triangular cylinder, *Ochanomizu Univ., Tokyo, natur. Sci. Rep.* **7,** 1, 10–24, 1956.

Measurements were made of the pressure distribution on the surface and of the velocity distribution in the wake of an equilateral triangular cylinder placed in a closed air stream for the range of Reynolds numbers from 4×10^4 to 8×10^4. The drag and base pressure are well correlated when interpreted by Roshko's modified free-streamline theory. It is also pointed out that a considerable effect of inflow makes the results erroneous if the cylinder is placed in a free-jet air stream. I. Tani, Japan

3762. Molyneux, W. G., Ruddlesden, F., and Cutt, P. J., Technique for flutter tests using ground-launched rockets, with results for unswept wings, *Aero. Res. Counc. Lond. Rep. Mem.* no. 2944, 19 pp., 1956.

3763. Letko, W., Experimental investigation at low speed of the effects of wing position on the static stability of models having fuselages of various cross section and unswept and 45° sweptback surfaces, *NACA TN* 3857, 77 pp., Nov. 1956.

An experimental investigation was made to determine the effects of wing position on the low-speed static longitudinal and static lateral stability derivatives of airplane models having fuselages of square and rectangular cross sections and unswept and 45° sweptback surfaces. The horizontal tail of each model was located on the fuselage center line.

The results of the investigation indicate that at low angles of attack the complete unswept models with the wing in the high position are more stable or least longitudinally unstable; whereas, for the swept models there is little change in longitudinal stability with changes in wing position. For both the swept and unswept complete configurations, the low-wing position is generally the least stable in the medium angle-of-attack range; whereas, at high angles of attack, there is little significant difference in the stability of the models due to wing position. The results also show that, in the low and medium angle-of-attack range, moving the wing from the low to the high position generally causes a decrease in the directional stability for both the swept and unswept configurations. The low-wing configuration is indicated to have the smallest detrimental effects caused by sidewash on the tail contribution to the static lateral stability derivatives for almost the entire test angle-of-attack range.

The results also show that wing-fuselage interference causes an increase in effective dihedral angle when the wing is moved from the low to the high position, as occurred for the circular cross-section fuselage reported on in previous investigations.

From author's summary

3764. Barrere, Mme. S., Spectrographic study of deflagration waves in a laminar region, *Rech. aéro.* no. 46, 15–24, 1955.

3765. Lawrence, T., Control effectiveness tests at transonic speeds on an EC. 1250 section with 0.25 chord concave control, *Aero. Res. Counc. Lond. Rep. Mem.* no. 2809, 7 pp., 1955.

3766. Henshall, B. D., Some notes on the flow durations occurring in hypersonic shock tubes, *Aero. Res. Counc. Lond. curr. Pap.* no. 290, 9 pp. + 6 figs., 1956.

Several methods for the production of very strong shocks are considered, including especially the double-diaphragm combustion-type shock tube. It is shown that the deviations from ideal gas theory, occurring when strong shocks are generated, appreciably reduce the available testing time. W. Wuest, Germany

3767. Henshall, B. D., The use of multiple diaphragms in shock tubes, *Aero. Res. Counc. Lond. curr. Pap.* no. 291, 30 pp. + 12 figs., 1956.

Calculations are presented which illustrate the advantages of various types of multiple-diaphragm shock tubes over the single-diaphragm conventional shock tube. General results are also derived for shock tubes with area discontinuities, expecially at the diaphragm station. A comparison is made of maximum attainable shock Mach numbers for various types of shock tube. It is shown that shock tubes with area discontinuities are only of interest for relatively small pressure ratios (say below 10^3). The double diaphragm technique (reflected shock type or unsteady expansion type) appears to be extremely simple and offers a considerable increase of shock Mach numbers. In view of the very large gains of shock Mach number indicated by the theory of multiple-diaphragm shock tubes with high over-all pressure ratios, there is a need for experimental investigation of these types of shock tubes. W. Wuest, Germany

3768. Henshall, B. D., and Gadd, G. E., Factors affecting the performance of the nozzle of a hypersonic shock tube, *Aero. Res. Counc. Lond. curr. Pap.* no. 293, 17 pp. + 12 figs., 1956.

An analysis of the starting process of a hypersonic shock tube is made, and the subsequent flow conditions in the working section are evaluated for various static temperatures and Mach numbers of the flow. The use of a diaphragm at the entrance to the nozzle is suggested in order to minimize the loss of testing time due to tunnel starting. A discussion of the simulation of free flight conditions leads to the recommendation of using two working sections, one in the constant area channel for stagnation temperature simulation and one following a divergent nozzle for Mach number simulation. W. Wuest, Germany

3769. Yoler, Y. A., Hypersonic experimentation, G-E Techn. Forum, New York City, N. Y., Apr. 3, 1956. 5 pp.

3770. Stevens, R. G., Borden, A., and Strausser, P. E., Summary report on the development of a hot-wire turbulence-sensing element for use in water, *David W. Taylor Mod. Basin Rep.* 953, 18 pp., Dec. 1956.

A summary is given of the work done since 1946 at the Taylor Model Basin to develop a hot-wire turbulence-sensing element for use in water and of some of the uses to which the wire has been put. Recent efforts to determine the causes of wire instability and to eliminate them are described. As a result, it was determined that these wires should be heated with an alternating carrier current and that the exposure of dissimilar metals in the probe assembly should be eliminated. With these precautions the wire could be stabilized in well-filtered water. In ordinary water, instability from the accumulation of dirt and surface film on the wire could not be controlled except by removing the wire frequently for cleaning. It appears that the only satisfactory solution to this problem lies in the development of a dynamic calibration technique. Theoretical expressions for the sensitivity and frequency response of a coated hot wire are included.

From authors' summary by L. S. G. Kovasznay, USA

3771. Wise, B., Steward, D. R., and Schultz, D. L., The hot-wire anemometer for turbulence measurements. Parts I–IV, *Aero. Res. Counc. Lond. curr. Pap.* 273, 8 pp. + 15 figs.; *curr. Pap.* 274, 5 pp. + 12 figs.; *curr. Pap.* 275, 33 pp. + 80 figs.; *curr. Pap.* 276, 16 pp. + 24 figs., 1956.

Although they were released only in 1956, the four reports are successively dated 1951–1954, covering development work on hot-wire anemometers at the Oxford University Engineering Laboratory. The principal contribution is the detailed study of "hybrid" hot-wire anemometer systems where both d-c and radio-frequency heating are present, and both positive and negative feedback may be employed. Standard electronic nomenclature is applied throughout, and the reports may be read with ease by electronic engineers. The fourth report contains some turbulent fluctuation measurements of a rather preliminary nature. The entire hot-wire signal is regarded as due to velocity (mass flow) fluctuations, and no attempts are made to interpret the readings from a fluid mechanical point of view. L. S. G. Kovasznay, USA

3772. Laufer, J., and McClellan, R., Measurements of heat transfer from fine wires in supersonic flows, *J. fluid Mech.* **1,** 3, 276–289, Sept. 1956.

Authors present a carefully executed, rather detailed set of measurements on the equilibrium temperatures and heat loss of fine cylinders in supersonic flow. The accurate evaluation of hot-wire measurement decisively depends on the availability of such data. The Mach numbers covered are from 1.33 to 4.54. The Reynolds numbers range from 3 to 200 and the overheating ratio 0–1. Plausibility arguments are also given in the discussion.

The paper is a valuable contribution and its results greatly assist workers in hot-wire anemometry.

L. S. G. Kovasznay, USA

3773. Magarvey, R. H., Stain method of drop-size determination, *J. Meteor.* **14,** 2, 182–184, Apr. 1957.

The size spectrum of rain drops in natural rain has been studied by many workers by catching raindrops on absorbent filter paper. The present research deals with the empirical determination of the relationship between the size of the stain on the absorbent paper and the diameter of the raindrop causing it. Simple theory suggests a functional relationship between drop diameter D and stain diameter S of the form: $D = a\,S^b$, in which b has the value 2/3. By the present experiments the actual value of b was found to be 0.75 for drops of greater than 1.5 mm, and 0.93 for drops of less than 1.5 mm. The value of a was found to be 1/3.

Streams of drops with high degree of size uniformity were produced with droppers based on the sensitive jet principle (Magarvey and Taylor, 1956 A and 1956 B), and photographed at a point, determined stroboscopically, at which the drops assumed a spherical shape. The drops were caught on Whatman no. 2 filter paper, moved transversely to the stream, which was dusted with finely powdered, water soluble, blue, aniline dye. The intercepted drops left a permanent blue stain on the paper. Stains were obtained from drops of 50 different sizes, varying from 0.5 to 10.5 mm in diameter. K. J. DeJuhasz, Germany

3774. Adler, C. R., Mark, A. M., Marshall, W. R., and Parent, R. J., A scanning device for determining size distribution of spray droplet images, *Chem. Engng. Prog.* **50,** 1, 14–23, Jan. 1954.

A scanning instrument is described for counting and classifying spray drop images on photographic negatives. These negatives, mounted on a rotating drum, are projected by an optical system and focused at the plane of a mask containing a small aperture and located directly in front of a photomultiplier tube. As the droplet images rotate past this aperture they are simultaneously advanced a small distance at each revolution of the rotating drum. Thus the phototube receives through the aperture a series of light pulses whose durations correspond to the lengths of the chords of the circular image of the drops passing across the aperture. These light pulses of various time durations are converted into electrical pulses and fed into electronic sorter-counter circuits which classify the chords into fifteen size classes. A statistical treatment of this chord distribution is then made to give drop-size distribution. Tables of coefficients have been computed to permit rapid conversion of the chord distribution to drop-size distribution. The statistical theory for these coefficients is explained.

Tests on actual spray samples and on special test negatives demonstrated that the device will rapidly count and classify drops with acceptable accuracy. The scanning rate can be as high as 10,000 drops in 15 min at maximum drum speed, with greater accuracy than could be done by a human operator. Its main limitation is that it requires transparent images on photographic negatives; this in turn requires sampling of sprays on greased or soot-coated slides and photographing them. Apparatus is described in detail; data on actual sprays are given, and plotted in frequency curves. K. J. DeJuhasz, Germany

Thermodynamics

(See also Revs. 3567, 3697, 3796, 3797, 3798, 3799, 3800, 3815, 3816, 3818, 3820, 3821, 3827, 3841, 3849)

3775. Rice, O. K., A kinetic approach to the thermodynamics of irreversible processes, *J. phys. Chem.* **61,** 5, 622–629, May 1957.

Irreversible processes are considered in terms of "transference units" or groups of molecules in a particular energy state capable of causing an exchange of molecules. Equilibrium consideration of such transference units with components of the solution and the relation of this equilibrium in a temperature and concentration gradient with an inverse unit (one capable of reversing the exchange of molecules) result in equations for the fluxes of matter and heat. Reciprocal relations between the phenomenological coefficients are derived from these equations. The Soret effect for thermocells is derived. Remarks on experimental values of heats of transport in electrolyte solutions are included. The extension to heterogeneous systems (which contain a membrane) is considered and illustrated by application to the Knudson flow of a gas. R. A. Gross, USA

3776. deBoer, J. Introduction to irreversible processes, *Univ. Wis. Nav. Res. Lab., Tech. Rep.* WIS-AF-2, 27 pp., July 1956.

3777. Kline, S. J., and Koenig, F. O., The state principle—some general aspects of the relationships among the properties of systems, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-4, 6 pp.

An independent generalization, here called the "state principle", is necessary for the development of thermodynamics. Previously, this principle has been either tacitly assumed, or at best stated incompletely. A discussion and explicit formulation of this principle are given. The phase rule is deduced from the state principle and certain related empirical information. In this derivation no reference whatsoever is made to the first law or the second law of thermodynamics. A new, simple, systematic means for counting the number of components in the phase rule, which has no known exceptions and which does not rely on either advanced thermodynamics or the first and second laws, is presented. Examples of its use are included.

From authors' summary by D. Altman, USA

3778. Moser, H., Otto, J., and Thomas, W., Thermodynamic gas measurements at high temperatures, I. A new gas-thermodynamic method (in German), *Z. Phys.* **147,** 1, 59–75, 1957.

Previous methods are based on constant volume or pressure; the new method, however, is based on constant temperature and variable volume and pressure. The accuracy of this new method is increased tenfold. A novel, very sensitive differential manometer is part of the apparatus. The method is reduced to a determination of a volume (by weighing with mercury), is suitable up to 1100C, and allows determination of the gold resolidification temperature to ± 0.1C. W. Gumz, Germany

3779. Moser, H., Otto, H., and Thomas, W., Gasthermometric measurements at high temperatures, II. Determination of the gold resolidification point (in German), *Z. Phys.* **147,** 1, 76–91, 1957.

Using the method mentioned in the preceding review has led to a new concise determination of the gold point (equilibrium temperature of liquid and solid gold) which was found to be

$$t_{Au} = 1064.76 \pm 0.1\text{C}$$

as against the former standard value of 1063C.

W. Gumz, Germany

3780. Larue, P., Optimal volume of gas container for the propulsion of liquid propelled rockets (in French), *ONERA NT* 54, 17–20, Nov.-Dec. 1956.

Polytropic expansion of gas from storage into propellant tanks induces Joule-Thomson cooling. Using an appropriate expression, integration is performed to evaluate cooling from storage pressure to propellant feed pressure. The cooling is combined with polytropic expansion to yield storage tank volume as function of polytropic exponent, Joule-Thomson coefficient, final storage, and feed pressures, and the initial gas state. For nitrogen gas pressurizing nitric acid the exponent is found experimentally to be 0.11 at pressures below 30 kg/cm². A relation between final feed and storage pressures is obtained, using empirical formulas, so as to avoid instability in feed pressure and excessive storage pressure drop. The remaining relations between storage tank volume, feed pressure, and initial state of the gas (temperature and pressure) are plotted for a narrow range of values.

R. A. Stern, USA

3781. Mamedov, A. M., Extension of the Bachinskii viscosity formula to the region of high pressure (in Russian), *Trudi Azerb. industr. in-ta* no. 9, 62–75, 1955; *Ref. Zh. Mekh.* 1956, Rev. no. 2896.

An attempt is made to extend the Bachinskii formula

$$\eta = \frac{c_b}{v - \omega}$$

to the region of high pressures. For this the free volume $v - \omega$ is expressed according to the Biron formula through the pressure p and certain constants B and C which are characteristic for the given liquid. Then the Bachinskii formula is written in the following way

$$\eta = c_b \frac{C + p}{B}$$

The constant c_b can be determined according to the test data. The values c_b are given for liquid hydrocarbons (propane, *n*-

butane, isobutane), ethyl and propyl alcohol, and water dependent upon temperature and pressure. A. I. Golubev, USSR
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

3782. Taylor, R. J., An electronic analogue of the saturated vapour pressure curve of water, *J. sci. Instrum.* **33,** 11, 436-438, Nov. 1956.

An analog of the saturated vapor pressure curve of water between 0 and 30C which is suitable for inclusion in a complete electrical simulation of the psychrometric equation is described. The stated range of temperature can be covered in three subranges of ten centigrade degrees, each with an accuracy in vapor pressure of a fraction of 1%. A theoretical analysis indicates that the slope of the curve, which is important in certain applications, is reproduced with 2% accuracy.
From author's summary

3783. Macaluso, C. A., An automatic, spray desuperheating, closed system for testing compressors, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-153, 10 pp.

The need, functions, and requirements of a closed system for testing centrifugal refrigeration compressors are presented. Suitable basic cycles are discussed and the desuperheating cycle is described in detail. Economic and engineering design criteria for a desuperheating system are given. Controls, instrumentation, operation, and electronic data-processing are treated in detail.
From author's summary

3784. Walsh, J. M., and Rice, M. H., Dynamic compression of liquids from measurements on strong shock waves, *J. chem. Phys.* **26,** 4, 815-823, Apr. 1957.

High explosives were used to drive strong shock waves into various liquids, and a moving-image camera was employed to determine velocities associated with the shock waves. The measured velocities are transformed to pressure-compression points by applying the conservation relations. The pressures attained vary among the 15 liquids studied but are typically in the range 50 kilobars to 150 kilobars. For water, more extensive experimentation suffices to determine the Hugoniot curve from 30 kilobars to 450 kilobars. The highest pressure for each of the liquids extends the available data range from static experimentation several fold.

A shock-wave reflection experimental method is described, the purpose of which is to measure the useful thermodynamic variable $(\Delta H/\Delta V)_p$ at high pressures. Results are given for water.

Qualitative experiments to study the transparency of shocked water, carbon tetrachloride, ethyl alcohol, and benzene are reported.
From authors' summary by W. R. Hawthorne, England

3785. Rice, M. H., and Walsh, J. M., Equation of state of water to 250 kilobars, *J. chem. Phys.* **26,** 4, 824-830, Apr. 1957.

An equation of state for water, applicable in the pressure range 25 kilobars to 250 kilobars, is formulated in terms of experimental data obtained from shock wave measurements. This equation of state is used to calculate P-V relations for several adiabats and isotherms. Thermodynamic and hydrodynamic data along the Hugoniot curve are given as a function of shock pressure, and pressure-particle velocity relations for initial shocks followed by reflected shocks and rarefactions are given.
From authors' summary by W. R. Hawthorne, England

3786. Duban, P., Some possibilities of using hot water for the propulsion of rockets (in French) *ONERA NT* 54, 9-16, Nov.-Dec. 1956.

Thermodynamic analysis of two-phase fluid flow from a rocket leads to a relation between mass ratio, heat loss, and quality of ejected fluid, involving state properties and assuming phase equilibrium. For short flow durations the heat loss rate is taken to be temperature-independent, and the mass ratio is obtained explicitly for ejected fluid qualities of 100% vapor, 0% vapor, and reservoir quality. Derived specific quantities—impulse, mass, efficiencies, etc.—are plotted as functions of temperature for the three qualities mentioned. Comparison with an average JATO unit shows that optimum equivalent hot-water rocket operates within 20 degrees of 300C, weighs twice as much, and is four times as bulky. Low initial temperature and high ejected fluid quality insure constancy of thrust. Cost and safety factors are discussed with a view to commercial aeronautics. R. A. Stern, USA

3787. Pitzer, K. S., and Curl, R. F., Jr., The volumetric and thermodynamic properties of fluids. III. Empirical equation for the second virial coefficient, *J. Amer. chem. Soc.* **79,** 10, 2369-2370, May 1957.

An equation has been developed to represent the second virial coefficient of a normal fluid: $BP_c/RT_c = (0.1445 + 0.073\omega) - (0.330 - 0.46\omega)T_r^{-1} - (0.1385 + 0.50\omega)T_r^{-2} - /(0.0121 + 0.097\omega)T_r^{-3} - 0.0073\omega T_r^{-8}$ where ω is the acentric factor (defined by $\omega = -\log (P/P_c)_{sat} - 1.000$ at $T_r = 0.7$) which was discussed in an earlier paper. This equation not only fits the volumetric data with considerable accuracy but its second derivative also yields agreement with measured values of the pressure derivative of the gas heat capacity. From authors' summary

3788. Druyvesteyn, M. J., and Van Ooijen, D. J., Change of the absolute thermoelectric power and electrical resistivity of copper by cold-working at liquid air and room temperature, *Appl. sci. Res.* (*B*) **5,** 6, 437-441, 1956.

3789. Van Ooijen, D. J., The thermoelectric power of cold-worked platinum between liquid air and room temperature, *Appl. sci. Res.* (*B*) **5,** 6, 442-444, 1956.

3790. Ono, S., A note on the variation principle in the kinetic theory of gases, *Sci. Pap. Coll. Gen. Educ., Univ. Tokyo.* **5,** 2, 87-96, Dec. 1955.

3791. Courvoisier, P., The solar engine: an analysis, *Mech. Engng., N. Y.* **79,** 5, 445-447, May 1957.

A simplified electric analog of a solar-collector steam-engine combination is used to deduce an expression for the efficiency of a solar heat engine. The main conclusion that the solar collector design is the decisive factor is in accord with other writers, and in particular with Hottel's [AMR **9,** Rev. 2693] more complete work in which exact performance equations, and cost data, are used in arriving at design optima. Present paper, being an oversimplification, is not exact quantitatively, but yields most useful and interesting conclusions. Author has not emphasized the close interdependence of his "absorptivity factor" a and "dimensionless temperature" t; the one increases as the other decreases. Also, author refers specifically to a steam engine, although his analysis is valid for any heat engine. A. Whillier, S. Africa

Heat and Mass Transfer

(See also Revs. 3565, 3566, 3567, 3569, 3705, 3717 3747, 3772, 3778, 3779, 3783, 3791, 3840, 3870)

Book—3792. Vidmar, M., Transformers [Die Transformatoren], 3rd ed., Basel, Verlag Birkhäuser, 1956, 630 pp. SFr. 64.

Book is written in German in a brilliant style and is generally considered to be an authoritative and excellent treatise of electric transformers. In its third edition published in 1956 it devotes a chapter of 150 pages to cooling problems. Only this area is within the scope of the present magazine and will be reviewed here. The

chapter contains sections on: the lifetime of a transformer, heat conduction in the iron and the coil, radiation, natural and forced convection, a discussion of design problems, and calculation of the heating of the transformer after starting and at interrupted operation.

The material contained in these sections consists entirely of design information which is of an empirical nature or is based on calculations considering very simplified models. It will be useful to the designer of transformers. The research-minded engineer, however, will miss an up-to-date discussion of the basic physical processes which determine the exchange of heat. As a matter of fact, in this respect the chapter on cooling problems is a proof of the astonishing fact of how long it takes knowledge of the advances in basic sciences to spread into various engineering areas. This becomes evident from the following observations. Only two works of a basic nature are cited: one by Dulong Petit in 1817 and one by Lorenz in 1881. The term turbulence is not even mentioned in the chapter on forced convection. The section on radiation introduces Stefan-Bolzmann's equation in the following way: "A number of relations have been developed for heat radiation. Among them one by Stefan-Bolzmann, on which the following calculations will be based." In the same chapter, the erroneous statement is made that the infrared heat radiation from the surface of a transformer can be increased by painting the transformer with a black color instead of a bright one.

Reviewer feels that use of the advances which the science of heat transfer has made during the recent decades would not only give the designer a better insight into the processes which he has to consider but also help in the admittedly difficult problem of predicting temperature conditions in a transformer.

E. R. G. Eckert, USA

3793. Barrow, H., Radial temperature distribution in an annular coolant passage, *Engineer, Lond.* **203,** 5285, 713–715, May 1957.

The dimensionless temperature profile across a long concentric annulus with constant heat velocity at the inner wall is calculated using as an average (constant) eddy diffusivity $\bar{\varepsilon}$ over the whole turbulent core the relation $\bar{\varepsilon}/\nu = 0.0075\, Re^{0.8}$ obtained by the author for air flowing in an annulus of ratio 2.25. ν is the kinematic viscosity and Re the Reynolds number.

In the laminar layer, the heat velocity is assumed constant at its wall value and the velocity zero. In the turbulent core, starting at a wall-distance parameter of 11.7, thermal conductivity is neglected and the velocity assumed constant at its average value over the whole channel.

The calculated temperature profile, when normalized, agrees moderately well with results observed by the author for air at Re from 16,000 to 47,000. The heat-transfer coefficient is not calculated.

C. F. Bonilla, USA

3794. Howland, W. E., Trabant, E. A., and Hawkins, G. A., A mechanical computing device for the analysis of one-dimensional, transient, heat-conduction problems, *Trans. ASME* **79,** 3, 675–680, Apr. 1957.

A graphical solution of the equation $(\partial u/\partial t) = \alpha(\partial^2 u/\partial x^2)$ is obtained as follows: The initial u is plotted against x at equal intervals (Δx). Chords are drawn between $u_0 - u_2$; $u_2 - u_4$; ... $u_{2n-2} - u_{2n}$. At the abscissae $x_1, x_3 \ldots x_{2n-1}$, the ordinates of the chords together with the values u_0 and u_{2n} form the skeleton of a graph representing u as a function of x at the time $(\Delta x)^2/\alpha$; repetition of this procedure results in a full solution of the equation consisting of $u - x -$ graphs at different times. Manipulation is simplified by stretching an elastic string along the initial graph and, by removing pegs, allowing the string to slide into the appropriate polygon of chords ("Hackemann idea").

In the present article, a number of possible applications of this procedure are put forward: radial heat flow in two or three dimensions; heat flow across the interface between two different solids; and, in particular, the nonlinear equation in which α depends upon u. So far, no computer has been built which is appropriate to these applications. Discussors of the paper acknowledged the principle of the method but queried its practical use.

Reviewer notices that the method does not require any expensive instruments, and that a computing device could readily be adapted to standard drawing equipment; it should accordingly be useful, provided that only moderate demands on accuracy are made.

R. Eisenschitz, England

3795. Bannister, F. K., Transient temperatures in racing-car brake drums, *Engineering* **183,** 4748, 304–308, Mar. 1957.

One-dimensional heat equation is solved for the case of a homogeneous slab at constant initial temperature, with a prescribed heat flux (function of time) at face $x = 0$, and with face $x = d$ insulated. Solution is used to determine temperatures occurring in a plain, unfinned racing car brake drum during a single stop.

G. M. Low, USA

3796. Butler, J. N., and Brokaw, R. S., Thermal conductivity of gas mixtures in chemical equilibrium, *J. chem. Phys.* **26,** 6, 1636–1643, June 1957.

Authors derive an expression for the thermal conductivity of gas mixtures whose composition varies with temperature as a result of one or several chemical equilibria among the chemical species present. Thermal diffusion and gravity (and hence free convection) effects are excluded from the analysis. In gas mixtures subjected to a temperature gradient and in which chemical reactions proceed with such rapidity that chemical equilibrium may be considered to prevail at all temperatures, heat is transferred not only by thermal conduction, but also by the transport of chemical enthalpy by the molecular diffusion of various chemical species in response to the concentration gradients caused by the temperature gradient and the dependence upon temperature of the chemical equilibrium composition. The component of over-all thermal conductivity due to this second mode of heat transport is shown to depend on the heats of the chemical reactions involved and on the binary diffusion coefficients among the chemical species in the system.

For two-component systems, the expression for effective thermal conductivity may be considerably simplified and expressed in terms of the equilibrium heat capacity, which quantity includes the effect of heat absorbed by endothermic chemical reactions shifting to the right as temperature is increased. Comparison of the two-component equation with experimental thermal conductivity data on $N_2O_4 — NO_2$ and $HF — H_6F_6$ mixtures shows good agreement.

The practical significance of this study lies in the fact that the effective thermal conductivity of equilibrium mixtures may be very much greater than that of nonreacting mixtures or pure components. As might be expected, the thermal conductivity is greatest when reactants and products are present in comparable concentrations, and it approaches that of a pure component or a nonreacting mixture when the equilibrium is displaced very far in one direction or the other. In the nitrogen oxide system, the thermal conductivity of the equilibrium mixture is up to ten times as great as that of the pure components. For the HF monomer-hexamer equilibrium, this ratio is as high as 30.

A. W. Gessner, USA

3797. Hsu, S. T., Theory of a new apparatus for determining the thermal conductivities of metals, *Rev. sci. Instrum.* **28,** 5, 333–336, May 1957.

Transient processes of heat conduction has become more or less a standard procedure for determining the thermal diffusivity $k/\rho c$ of heat-conducting materials. Author presents new laboratory experimental approach for determining diffusivity through transient heat conduction. The apparatus consists of two standard metal specimens whose initial temperature and thermal properties are known and two specimens whose initial temperature is known but

the thermal property is to be determined. Initially, the test specimens are sandwiched between the standard specimen and the temperature at the interface between the two test specimens is recorded with time. The value of the interface temperature at a given time substituted in the author's solution gives the heat diffusivity of the sandwiched test specimens.

Author claims that if a perfect contact in the interface is insured with a pressure of 150 lb/in.^{2} and a thin coating of graphite grease, results are estimated to be 3% accurate.

S. Eskinazi, USA

3798. Hill, R. A. W., Rapid measurement of thermal conductivity by transient heating of a fine thermo-junction, *Proc. roy. Soc. Lond. (A)* **239,** 1219, 476–486, Apr. 1957.

A method for the rapid measurement of the thermal conductivity or the specific heat of a poor conductor is presented. Method consists of analyzing a recording of the transient temperature change of a finely drawn thermo-junction which is in intimate contact with the conductor. Measurement time required is a fraction of a second.

Conductivities of three liquids have been measured. Results lie within the ten per cent of accepted values. Method presented is the specific method applied to the three liquids tested. Method variations are dependent upon the conductor to be tested and no general method is included, although a good description of the specific method used is included. C. C. Eckles, USA

3799. Beck, A., A steady state method for the rapid measurement of the thermal conductivity of rocks, *J. sci. Instrum.* **34,** 5, 186–189, May 1957.

The principle of constant temperature difference is used in a divided bar type of apparatus with which a measurement of the thermal resistance of a specimen can be completed within twenty minutes. A thick guard ring is used. The diameter of the specimens is made the same as the external diameter of the guard ring, and irregularities in disks, which would cause appreciable errors in a more conventional apparatus, can be tolerated and an accuracy of ±1% for a single measurement still be obtained.

From author's summary

3800. Briggs, L. J., Gallium: thermal conductivity; supercooling; negative pressure, *J. chem. Phys.* **26,** 4, 784–786, Apr. 1957.

The thermal conductivity of liquid gallium does not appear to have heretofore been measured. The method employed involves a comparison with the known thermal conductivity of mercury. The two liquids were sealed in two thin-walled glass tubes (30 cm long, 10-mm bore), the upper ends being inserted vertically through the bottom of a boiler containing boiling water. The tubes were coated to secure the same thermal emissivity. Two thermocouple loops which could be moved along the tubes served to establish points having the same temperature on the two tubes. The ratio of the squares of the lengths from the thermocouple junctions to the bottom of the boiler gave 3.51 ± 0.03 as the relative thermal conductivity of gallium to that of mercury, or 0.336 ± 0.005 watt/cm (°C) as the thermal conductivity of gallium between 30 and 100C, based upon 0.0958 for mercury.

It was found possible to supercool liquid gallium to −28C, or 58C *below* its melting point, by exposing small drops on paper to a slowly decreasing temperature in a deep-freeze chamber with a circulating atmosphere.

An attempt to measure the negative pressure of gallium proved disappointing, for it was found that gallium does not "wet" the wall of an evacuated tube. With a partial evacuation, low negative pressures were measured which decreased (like water) as the melting point was approached. From author's summary

3801. Churchill, S. W., Abbrecht, P. H., and Chu, C.-M., Regenerative heat transfer in two- and three-dimensional flow through porous media, *Indust. Engng. Chem.* **49,** 6, 1007–1012, June 1957.

Methods for solving, and analytical solutions of, heat transfer between a fluid and a porous solid through which it passes are reviewed. The solutions given are for one-dimensional flow, but can be applied to two- and three-dimensional flow if the directions of the streamlines can be determined by potential theory or an analog. The static heat capacity of the fluid is neglected, but any initial solid temperature distribution and inlet fluid temperature can be employed. Simpler solutions, adequate for most applications, are obtained by neglecting the temperature difference between the fluid and solid.

The solutions quoted can also be applied to mass transfer and to flow in channels, as well as in porous beds.

C. F. Bonilla, USA

3802. Stewartson, K., and Jones, L. T., The heated vertical plate at high Prandtl number, *J. aero. Sci.* **24,** 5, 379–380, May 1957.

3803. Petrou, L., Study of free and forced convections in the case of wires parallel with the flow, *C. R. Acad. Sci. Paris* **239,** 19, 1187–1189, Nov. 1954.

3804. Zucrow, M. J., and Graham, A. R., Some considerations of film cooling for rocket motors, *Jet Propulsion* **27,** 6, 650–656, June 1957.

It is demonstrated experimentally that increasing the film-cooled length of a cylindrical section requires more than a proportional increase in the film-coolant rate. It is shown that, if the heat-transfer rate to the liquid film is known, an ideal film-coolant flow rate may readily be calculated which is proportional to the average film-cooled length. The actual film-coolant flow rate may then be determined from the graphs presented in the paper. Circumferential variations in the length of the liquid film may be taken into account by means of the profile effectiveness which depends upon the design of the film-coolant injector and the main propellant injector. A method for estimating the heat transfer to the film coolant is presented. Experimental data are also presented for the loss in specific impulse when water is used as the film-coolant. The rocket motor experiments reported herein were conducted with a 500-lb-thrust, 500-psia combustion pressure rocket motor using white fuming nitric acid and jet engine fuel (JP-4) as the propellants.

From authors' summary by R. L. Young, USA

3805. Rubesin, M. W., and Inouye, M., A theoretical study of the effect of upstream transpiration cooling on the heat-transfer and skin-friction characteristics of a compressible, laminar boundary layer, *NACA TN* 3969, 41 pp., May 1957.

Reviewer considers this report to be a significant contribution to boundary-layer theory. Authors consider integral form of boundary-layer equations and "match" the profiles of temperature and velocity at the place where the porous wall ceases and the solid wall begins. Skin friction and heat transfer on downstream region are predicted. Heat transfer and skin friction increase from porous wall value to asymptotic value over solid wall. Method advanced is quite general and represents logical extension of previous Rubesin contributions to convection over nonisothermal surfaces. M. Tribus, USA

3806. Mirzajanzade, A. Kh., and Mirzoyan, A. I., Heat exchange in the constrained motion of a viscous-plastic liquid in a circular cylindrical tube (in Russian), *Dokladi Akad. Nauk AZSSR* **11,** 5, 313–318, 1955; *Ref. Zh. Mekh.* 1956, Rev. 4502.

The steady-state heat flow in the viscoplastic region is solved for the constrained motion of an incompressible fluid. The velocity and temperature gradients are assumed to be small; $\partial^2 T/\partial^2 Z$ is small against terms containing derivatives in r. For the plastic region, the temperature is assumed to be constant radially. A constant temperature of the tube and in the entry cross section of the fluid are assumed, with continuity of the temperature at the wall and of the temperature and heat flow on the viscous-plastic interface. The temperature field in the fluid is determined. An equation is given for the heat flow.

Courtesy Referativnyi Zhurnal G. F. Shaidurov, USSR
Translation, courtesy Ministry of Supply, England

3807. Petrikhov, B. S., A method of determining the local heat losses in a fluid flow in pipes and ducts (in Russian), *Izv. Vses. teplotekh. in-ta* no. 8, 18–20, 1953; *Ref. Zh. Mekh.* 1956, Rev. 4535.

Paper describes an improvement to the method for determining the local heat emission in a pipe flow, already suggested by M. A. Mikheev and I. T. Aladyev [I. T. Aladyev, *Izv. Akad. Nauk SSSR Otd. tekhn.* no. 11, 1951], consisting in weighing a portion of the condensate forming on certain parts of the outer surface of the pipe when it is heated by the steam.

For the purpose of a continuous measurement of the flow of condensate and of eliminating any possible error due to evaporation or secondary condensation, the author suggests determining the flow volume from the hydraulic resistance of a capillary tube into which the condensate is directed in a laminar flow.

Experimental verification of this suggestion has confirmed its practicability. K. D. Vaskresenskii, USSR
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

3808. Hall, N. A., Flow equations for multicomponent fluid systems, Part I, General equations; Part II, Binary layer equations, Univ. Minnesota, Heat Transfer Lab., TN no. 2, 1–33, Aug., 1955.

3809. Scott, R. F., Estimation of the heat-transfer coefficient between air and the ground surface, *Trans. Amer. geophys. Un.* **38,** 1, 25–32, Feb. 1957.

For the purposes of programming a computer to predict the depths of freezing and thawing in soils, a simple method is outlined with the appropriate charts for calculating the value of the surface heat-transfer coefficient, based on meteorological information which is normally easily obtainable. All the significant parameters are included, and an account of the investigation leading to the preparation of each chart is given.

From author's summary

3810. Seban, R. A., and Casey, D. F., Heat transfer to lead bismuth in turbulent flow in an annulus, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56–A–62, 3 pp.

Heat-transfer coefficients for molten lead-bismuth eutectic are presented for flow in annuli externally heated at a constant rate. Diameter ratios of 1.30 and 1.74 were investigated and results were obtained for Peclet numbers from 400 to 1600. These results are shown to be related to analogy predictions for this system in the same manner as exists for pipe flow; they also show that the theories providing a rationalization of the results for pipe flow do so as well for the flow in an annulus.

From authors' summary

3811. Jones, C. E., and Monroe, E. S., Jr., Convection heat transfer and pressure drop on air flowing across in-line tube banks, Part I. Apparatus, procedures, and special effects, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56–A–126, 8 pp.

This paper, the first of two companion papers, describes the equipment and computational methods used in an experimental program carried out at Cornell University, under the sponsorship of The Babcock and Wilcox Company. Eighteen arrangements of 10-row, in-line tube banks were tested for crossflow heat-transfer and flow-resistance performance, and sixteen additional arrangements were tested for flow resistance only. The interaction of transverse tube rows, the effect of tube-bank turbulence, the effect of temperature level, and the noise associated with some abnormally high flow resistances are discussed. From authors' summary

3812. Gram, A. J., Jr., Mackey, C. O., and Monroe, E. S., Jr., Convection heat transfer and pressure drop of air flowing across in-line tube banks, Part II. Correlation of data for ten-row-deep tube banks, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56–A–127, 13 pp.

New heat-transfer and pressure-drop data within a Reynolds number range of 600 to 40,000 obtained from model 10-row in-line tube banks are presented in a conventional form. The new data are compared with previously reported results for similar surface arrangements. By a process of cross-plotting, heat-transfer and pressure-drop factors are shown as a function of tube-bank arrangement in a series of curves at constant Reynolds numbers. Correlations for tube-bank geometry are proposed and the precision with which they represent the new and previously published data is discussed. From authors' summary

3813. Friedlander, S. K., and Johnstone, H. F., Deposition of suspended particles from turbulent gas streams, *Indust. Engng. Chem.* **49,** 7, 1151–1156, July 1957.

Rate of deposition of solid particles on the wall of a vertical circular tube was measured experimentally. Adhesive materials on the test-section pipe walls were used to trap the particles. The test section was located in a zone of fully developed turbulent boundary layer. For purposes of analysis, the flow zone was divided into three regions, central core, intermediate, and laminar sublayer. The one-dimensional steady-state diffusion equation was applied to each region. The diffusion coefficients of each region were taken from empirical data of others. Particle properties were introduced into the analysis by means of a "stopping distance" based upon the particle inertial reaction and the drag force exerted on a small spherical particle. The diffusion equation within the laminar sublayer was assumed to apply within one "stopping distance" of the wall. The experimental results were in reasonable agreement with the analytical results.

M. R. Carstens, USA

3814. Benson, G. W., The evaporation of fuel sprays. 1-theoretical treatment, *Nat. aero. Establish. Canad.* LR-181, 47 pp., Nov. 1956.

Two models have been proposed which will predict the rate of evaporation of a spray in which the mutual effects of adjacent drops are important. The models make approximations to reality and give relatively simple final equations of identical form, but slightly different numerical values for the parameters. More exact treatments are possible but they result in more complicated expressions for the evaporation. These expressions can be shown to reduce to the more simple form in the limiting case of low volatility sprays. The advantage of the present treatment is its simplicity and the fact that it leads to the definition of evaporation parameters that should be useful in experimental work. Also given are a detailed mathematical derivation of terminal velocities and Reynolds numbers of freely falling drops, analysis of evaporation of a single isolated stationary drop, and that of a droplet in a spray. Previous researches of other workers are surveyed; among these the work done at University of Michigan (Tribus, Klein, Rembowski, 1952) is examined in detail and the equation found is reduced to a simpler form. Comparison of saturation times for homogenous sprays is given. K. J. De Juhasz, Germany

3815. Berman, L. D., Theory of heat exchange in the condensation of steam in a bundle of horizontal tubes (in Russian), *Izv. Vses. teplotekh. in-ta* no. 3, 5–12, 1953; *Ref. Zh. Mekh.* 1956, Rev. 4537.

It is demonstrated that the usual conception today, founded on the work of Nusselt, concerning the mechanism of heat exchange in the condensation of steam on bundles of horizontal tubes is not confirmed by the experimental investigation of this process.

Author is of the opinion that the drop in heat transmission with progressive travel of the steam along the tube bundle is principally due to the decrease in velocity of the condensing steam, and only partially to the increase in thickness of the film of condensate owing to its flowing from the upper tubes on to the lower.

Courtesy Referativnyi Zhurnal K. D. Voskresenskii, USSR
Translation, courtesy Ministry of Supply, England

3816. Fuchs, S. N., The condensation of steam in motion on a horizontal pipe (in Russian), *Izv. Vses. teplotekh. in-ta* no. 3, 12–17, 1953; *Ref. Zh. Mekh.* 1956, Rev. 4534.

An experimental and analytical investigation of the heat emission from steam in motion, during condensation on a horizontal pipe placed transversely to the flow.

An equation in nondimensional quantities is given, obtained from evaluation of the experimental results at low steam pressures. An approximate calculation is made of the heat loss under these conditions for a laminar flow in the condensate film.

The experimental and analytical results diverge considerably, which is explained by the author as due to the presence of molar heat transfer in the film. K. D. Voskresenskii, USSR
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

3817. Chalmers, B., Melting and freezing, *J. Metals* **6,** 5, section 1, 519–532, May 1954.

3818. Wadleigh, K. R., and Oman, R. A., Instrumentation to measure gas-phase composition of high velocity, two-phase, two-component flows, *Jet Propulsion* **27,** 7, 769–775, 783, July 1957.

The problems associated with the measurement of the properties of high-velocity flows of liquid droplets suspended in gases are discussed. Emphasis is placed on the flow of liquid water droplets suspended in air-water vapor mixtures, with water-air mass ratios up to 0.3 and flow velocities from 350 to 600 fps. The mechanism of operation and the development of special probes to remove "true point samples" of the gas phase alone are described, as well as the devices for analyzing the composition of samples removed by these probes. Evaporation cooling device, "aero-thermopressor," is described for producing a rise in stagnation pressure of a high-velocity, high-temperature gas stream, by means of injected liquid water. Measurement of local value of specific humidity by means of humidity probe is described; humidity analyzer and its flow diagram are described. Approximate evaluation of errors in droplet "shedding" process of vapor sampling probe is given mathematically.

K. J. DeJuhasz, Germany

3819. Glawe, G. E., A high temperature combination sonic aspirated thermocouple and total pressure probe, *Jet Propulsion* **27,** 5, 543–544, May 1957.

3820. Barber, R., Meachen, D., and Bateman, W., The B.I.S.R.A. suction pyrometer for open-hearth furnace uptakes, *J. Iron Steel Inst. Lond.* **185,** pt. 3, 343–347, Mar. 1957.

Paper discusses operating experiences with a suction pyrometer having its refractory shield inside a water-cooled probe. The instrument was reasonably accurate and had a much improved life over other designs for the 1000–1400C range. Installation and operating techniques designed to maximize accuracy and long life are also discussed. R. J. Mindak, USA

3821. Henshaw, D. H., and Daw, D. F., Design of total temperature probes, *Nat. aero. Establ. Canad.* LR-184, 37 pp. + 2 tables + 40 figs. + 7 Appendixes, Jan. 1957.

A laboratory report summarizes the design, testing, and evaluation of several configurations of bare wire thermocouple total temperature probes. The discussion and evaluation of the various errors is quite complete. Ample illustrations are provided, including graphs of the flow nets with stream functions evaluated in the grid system for several theoretical incompressible flow patterns. For high-speed, high-altitude flight, the probes would have to be modified to reduce errors. The time constant for each probe was of the order of 0.5 seconds. Those not proficient in this field but interested in the design of total temperature probes will find this report interesting reading. R. J. Mindak, USA

3822. Saltzman, A. R., Plizak, B. T., and Tomko, L. F., Electronic equipment cooling by simultaneous heat and mass transfer, *Aero. Engng. Rev.* **16,** 5, 67–74, May 1957.

Paper describes the use of the latent heat of water vapor for cooling electronic equipment. The principle is illustrated by the wet-bulb thermometer where the bulb is colder than the surrounding air blowing over it, the heat being lost to continually evaporating moisture, the resulting water vapor being removed by mass transfer. A theoretical treatment based on N.T.U. concepts is given.

This technique can be used with the high-temperature, low-density air available in present day military aircraft. Some rather unsatisfactory experimental data are included. There is no doubt that the method is of appreciable importance.

G. G. Thurlow, England

3823. Issachenko, V. P., Heat loss from tube bundles in a cross-flow of various liquids (in Russian), *Teploenergetika* no. 8, 19–22, 1955; *Ref. Zh. Mekh.* 1956, Rev. 4530.

The heat emission is determined from the rows of seven-row bundles of tubes in parallel and staggered arrangement, for $s_1/d = s_2/d = 2$, by calorimetric measurements on a single central tube shifted from row to row and acting alternately as a heat transmitter and receiver. Without furnishing factual data, author asserts that the justification for this local simulation has been verified by him for Reynolds numbers between $R = 600$ and 1400. The fundamental researches, on the other hand, cover a range of $R = 500 - 130{,}000$. The inaccuracy introduced by the deviation of the locally measured temperatures from the temperature of the wall is also insufficiently evaluated. An expression is recommended:

$$N_f = CR_f^n P_f^{0.33}(P_f/P_w)^{0.25}$$

(*N Nusselt* number; *P* Prandtl number) in which, for staggered bundles, $n = 0.60$, $c = 0.415$, and for parallel bundles, $n = 0.65$, $c = 0.235$. In the experiments, the ratio P_f/P_w was varied between 0.48 and 2.7. V. S. Zhukovskii, USSR
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

3824. Krapivin, A. M., The heat process in a water-jet heat exchanger (in Russian), *Tekhnika Zh. D.* no. 6, 27–29, 1953; *Ref. Zh. Mekh.* 1956, Rev. 4531

The results of experimental research on the working of a water-jet heat exchanger are given. The nature of the influence of form of construction and working conditions of the heat exchanger on its fundamental thermal characteristics is determined. An empirical formula is presented for determining the coefficient of heat emission of a heat exchanger. Author suggests an arrangement for intensifying the process of heat transfer in a water-jet heat exchanger. S. S. Grigoryan, USSR
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

3825. Tinker, T., Shell-side characteristics of shell-and-tube heat exchangers, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-123, 18 pp.

A simplified rating system for commercial shell-and-tube heat exchangers is developed based on the fluid-flow-pattern concepts derived by the author for the General Discussion of Heat Transfer, London, 1951. Recommended heat-transfer and friction characteristics for practical design purposes are presented which are based on previously presented research data and certain findings of the ASME—University of Delaware Heat Exchanger Research Project. Where possible without serious sacrifice in accuracy, certain resistance-factor approximations and assumptions have been introduced in the interest of practical simplicity for the derivation of formulas of simple form for evaluating the fluid-flow fraction through the crossflow area of the tube bundle. Simple tabulations of heat-transfer and pressure-drop characteristic "rating numbers" may be readily developed from these formulas for various styles or series of heat exchangers having consistent design proportions. These rating numbers permit a rapid rating of the heat-exchanger shell-side performance. The system is responsive to the major effects of unit size, tube size, tube pitch and flow orientation, baffle spacing and cut, and the principal leakage and by-pass clearances of the heat-exchanger design. The system developed is accurate well within practical commercial requirements, and is very flexible, so that as more accurate resistance factors are developed by research for specific cases, they may be employed in the system for more precise results when desired. From author's summary

3826. Stevens, R. A., Fernandez, J., and Woolf, J. R., Mean-temperature difference in one, two, and three-pass crossflow heat exchangers, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Paps. 55-A-89 and 55-A-90, 11 pp.

Review of mean-temperature difference equations is given in compact tabular form for two-pass and three-pass countercrossflow and for two-pass and three-pass crossflow heat exchangers. Numerical integration methods were used to solve the case of a single-pass crossflow heat exchanger with both fluids unmixed, and all previously unsolved cases of two- and three-pass crossflow heat exchangers. The results of these numerical integrations are presented in form of correction factors for design purposes. The results are primarily useful to those engaged in heat-exchanger design. J. Kaye, USA

3827. Hiester, N. K., Tietz, T. E., Loh, E., and Duwez, P., Theoretical considerations on performance characteristics of solar furnaces, *Jet Propulsion* **27,** 5, 507-513, May 1957.

Performance theory of parabolic-type solar furnaces, together with curves of heat flux and maximum temperature at the focus, is presented. The theory is extended to the California Institute of Technology lens-type furnace. The paper will be of invaluable assistance to those working on solar furnaces, and should be studied along with others as published in *Journal of solar Energy Science and Engineering*, **1,** Apr.-July, 1957.

A. Whillier, S. Africa

Combustion

(See also Revs. 3554, 3608, 3672)

3828. Carpenter, D. L., The explosibility characteristics of coal dust clouds using electric spark ignition, *Combustion and Flame* **1,** 1, 63-93, Mar. 1957.

Observed maximum pressures are considerable lower than calculated, due to incomplete combustion, nonuniform distribution of dust, and transparency of gases. Pressure rise shows greatest increase for coals of 6-20% vol. m., very little for higher-rank coals. Gas-solid oxidation is responsible for the initiation of propagated combustion as revealed by studying the effect of admixed inert dust, prior oxidation, and blending explosive and nonexplosive dusts. From author's summary by W. Gumz, Germany

3829. Hartmann, I., Recent research on the explosibility of dust dispersions, *Indust. Engng. Chem.* **40,** 752-758, 1948.

Review of the nature of dust hazard and the importance of dust explosions; discussion of the various chemical and physical factors that affect dust explosibility; description of research in this field by U. S. Bureau of Mines. Explosions can be caused by dusts ranging from the finest particles to 700 micron (abour 20-mesh) diam. The lower explosive limit of coal dust in air is of the order of 35 milligrams per liter, i.e., about 0.035 ounce per cu ft. The conditions necessary for an explosion are a sufficiently dense dust cloud in an atmosphere that will support its combustion, and a source of ignition that will heat a portion of the cloud to ignition temperature. The destructive effects of a dust explosion are mainly determined by the maximum pressure, the rate of pressure rise, the duration of maximum pressure, and, in some cases, the negative pressure following the explosion. These in turn are influenced by: the chemical and physical properties of the dust, the concentration and uniformity of the dust cloud, properties of the atmosphere in explosion space, ignition source, characteristics of explosion space.

The experimental work described here includes determination of the following properties: particle-size distribution (by sieving), moisture content, ignition temperature of dust cloud, and of undispersed dust layer, relative inflammability of dust cloud, minimum ignition energy required (by electric spark from condenser discharge), lower explosive limit, maximum pressures and rates of pressure rise developed by dust clouds of various concentrations, limiting percentage of oxygen in atmosphere below which dust cloud cannot be ignited. Methods of measuring these properties are described, and properties defined by tables and charts. Most effective preventive measure against dust-explosion damage is the provision of an adequate relief opening or valve; some data on the size required are given. K. J. DeJuhasz, Germany

3830. Browning, J. A., and Krall, W. G., Effect of fuel droplets on flame stability, flame velocity, and inflammability limits, Fifth symposium (international) on combustion. Combustion in engines and combustion kinetics, Univ. of Pittsburgh, Pittsburgh, Pa., Aug. 30-Sept. 3, 1954, 159-163. New York, Reinhold Publishing Corp., 1955.

Combustion characteristics of atomized liquid fuel and air mixture are largely determined by the size of particles being burned. Assume the flame of a Bunsen burner, originally supplied with gaseous fuel and air, in laminar flow, and a steady flame front established thereby. Imagine that the gaseous fuel is replaced by atomized liquid fuel having uniform drop size. If these droplets are sufficiently small, they will be evaporated completely prior to entering the zone of combustion, and the laminar flame front will continue to exist. Substitute now a liquid fuel composed of large droplets which do not vaporize completely before entering the zone of combustion; in this case the flame front will collapse and each droplet will be surrounded by its own diffusion flame. The experiments made by author to investigate these flame phenomena comprise a method for determining the droplet size, by means of optical scattering techniques, on a kerosene mist composed of droplets within a 0.5 and 1.0-micron diameter range. The optical diffraction apparatus is illustrated and described. The relationship between the incident light and transmitted light is given by the Lambert-Beer equation. The light-scattering properties of a mist depend on the individual droplet size, the uniformity of droplet size, the index of refraction of the liquid forming the mist, the concentration of droplets per unit volume of mixture, the path length through which the light passes, and the wave length of the

light beam. Inasmuch as there are two unknown variables, i.e. particle size and the concentration of droplets, therefore two different wave lengths of light must be used, whereby two simultaneous equations are obtained. Several references are cited for a detailed explanation of the method.

K. J. DeJuhasz, Germany

3831. Speisher, V. A., Flame distribution and stability of the combustion zone (in Russian), Moscow, Vses. zaoch. energ. in-t, 1953, 40 pp.; *Ref. Zh. Mekh.* 1956, Rev. no. 2714.
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply

3832. Hottel, H. C., Toong, T.-Y., and Martin, J. J., Flame stabilization in a boundary layer, *Jet Propulsion* **27,** 1, 28–30, 48, Jan. 1957.

Flame stabilization was studied by visual observations of a lean premixed propane-air mixture burning along a rod stabilizer mounted axially in a 3.16-in. diam Pyrex glass cylinder. Stabilizer rod was water-cooled except for leading section consisting of tapered cone 5.6 in. long from cylindrical section $\frac{5}{8}$-in. diam to point at leading edge. Boundary velocity gradient was calculated from observed distance from point of stabilizer to flame front, assuming Blasius profile

$$(\partial u/\partial y)_w = 0.332\ (u_\infty/x)\ (u_\infty x/\nu_\infty)^{1/2}$$

where u_∞ is the free-stream velocity, x is the distance from point of stabilizer to flame front, and ν_∞ is the kinematic viscosity at free-stream conditions. Velocity u_∞ ranged from 2.4 to 5 fps, fuel from 0.7 to 0.8 stoichiometric, with air-fuel mixture at normal room temperature. Calculated velocity gradient seemed insensitive to position in Pyrex duct until flame is within 5 inches of duct exit. Velocity gradient increased slightly with free-stream velocity and with increase in temperature of water-cooled stabilizer (latter temperature having little direct significance). Main influence on velocity gradient was fuel-air ratio—gradient at 0.72 stoichiometric being 110 sec^{-1} and at 0.78 stoichiometric, 360 sec^{-1}.

D. Aronson, USA

3833. Teplitsky, M. G., Blast injection in a chamber-type boiler furnace (in Russian), *Izv. Akad. Nauk KazSSR, Ser. Energ* no. 7, 51–58, 1954; *Ref. Zh. Mekh.* 1956, Rev. 4552.

The results are given of investigations on the trajectory of a blast-injection flame made in the furnace of an NZL. 60–34 standard steam boiler by "staining" with magnesium powder. It has been found that the process of propagation of the flame jet in the furnace gases approaches the isothermal, and comparison of the calculated with the experimental trajectory demonstrates the possibility of calculating the two-dimensional blast jet as an isothermal free jet by the method of G. N. Abramovich ["Turbulent free jets in liquids and gases," Moscow, Gosenergoizdat., 1948], with ensuing geometric addition of the jet velocity and the velocity of the carrying flow.

It should be noted that the efficacy of application of blast injection was verified in appreciably substandard conditions.

No mention is made in the paper of the laboratory tests on the trajectories of blast injection jets described in a paper by Yu. Y. Ivanov [Kotloturbostroyenie no. 8, 14–19, 1952].

Courtesy Referativnyi Zhurnal E. A. Nakhapetyan, USSR
Translation, courtesy Ministry of Supply, England

3834. Anson, D., Influence of the quality of atomization on the stability of combustion of liquid fuel sprays, *Fuel* **32,** 1, 39–51, 1953.

Combustion experiments with kerosene sprayed from an air-blast atomizer. By using a series of different injection pressures a family of curves was obtained representing the weak limits of stable combustion for each case. It was possible to relate the stability limit at a given airstream velocity to the spray mean particle size. Fine atomization was found to extend the range of stable combustion, but an optimum particle size may exist for any given scale of turbulence in the combustion chamber. The apparatus comprised a centrifugal blower which could supply up to eight pounds of air per minute, which could be regulated and measured; the kerosene fuel was fed under pressure up to about 60 psi, at an adjustable temperature and at an adjustable rate; atomization was by air blast, whereby the relative proportion of blast air and fuel could be regulated; the flame tube was fitted with mica windows; ignition was by platinum wire. The results of the tests are represented in curves. K. J. DeJuhasz, Germany

3835. Bolt, J. A., and Boyle, T. A., The combustion of liquid fuel spray, *ASME Trans.* **78,** 3, 609–615, Apr. 1956.

Evaporation and combustion of liquid fuel spray in the range of drop sizes used in aircraft gas turbine combustors. Spray of uniform size fuel drops of 70 to 130 micron diam was produced by means of a spinning disk. Photographic techniques were developed to obtain the rate of change of diameter and the velocity of the burning drops, while moving freely in the air. Rates of burning for several pure hydrocarbon fuels were determined. The experimental work emphasizes the complexity of the combustion of fuel spray and the need for further research. Spray velocity was determined by using two photolights, the second being fired a known time-interval after the first. The distance between the two images of a drop permits the determination of the drop velocity. The photolights directed the light through a half-silvered mirror to the spray, and thence to the camera. The data indicate a linear relationship between the diameter squared and time. The burning process creates a high degree of turbulence, which causes the drops to vaporize at different rates; as a result the uniformity of drop diameter in the spray decreases as the burning proceeds. Previous researches by Spalding, 1950 and 1951; Godsave, 1951; May, 1951; Walton and Prewett, 1949; and Kobayashi, 1954 and 1955, are reviewed. K. J. De Juhasz, Germany

3836. Penner, S, S., and Fuhs, A. E., On generalized scaling procedures for liquid-fuel rocket engines, *Combustion and Flame* **1,** 2, 229–240, June 1957.

Generalized scaling rules are derived for four cases: (I) Similarity of steady combustion requires constant Reynolds number and constant ratio of residence time to reaction time (taken proportional to the product of empirical powers of mean droplet size and pressure). (II) Similarity of regenerative cooling requires a constant fraction of the total heat to be transferred to the walls. (III) Similarity of low-frequency instability depends on coupling between fuel supply and combustion chamber. (IV) Similarity of high-frequency instability is governed by the ratio of wave propagation time to reaction time. The set of generalized scaling rules following from these assumptions is compared with previous more specialized rules of Penner-Tsien, Crocco, and Barrère.

The results show the impossibility of maintaining complete similarity in regard to all the foregoing effects simultaneously. To satisfy the criteria even partially, more empirical knowledge of the reaction time is needed. This is a basic paper on combustion scaling. R. Friedman, USA

3837. Carman, E. P., Graf, E. G., and Corey, R. C., Combustion of solid fuels in thin beds, *U. S. Bur. Mines, Bull.* 563, 92 pp., 1957.

Tests were conducted to provide data that would aid in more efficient design of combustion equipment. Traveling-grate-stoker firing was simulated and crossfeed stoker firing done in modified traveling-grate test furnace.

Among factors studied were initial ignition time for surface of bed, amount of absolute radiant heat received by fuel, travel of ignition through fuel bed, and burning after ignition reached grate.

Tests were made using coke and coals of various ranks and sizes.

For traveling- or chain-grate stokers, initial ignition is more rapid for small sizes of high rank coals and large sizes of low rank coals at low air rates, but more rapid for large sizes of high rank fuel and small sizes of low rank coal at high air rates. Generally, ignition of low rank coals is more rapid. Above 8%, moisture content retards ignition, but below 8% it has little effect. Ignition travel through bed is more rapid with smaller sizes, with bituminous coals, and with preheated air (most rapid combination). Ash content has little effect on initial ignition, but high ash coals slow ignition through bed.

This work is an extension of earlier work on solid fuel beds by the U. S. Bureau of Mines. Reviewer believes that the data will be useful in design and operation of stokers.

M. Popovich, USA

Acoustics

(See also Rev. 3721)

3838. Biot, M. A., and Tolstoy, I., Formation of wave propagation in infinite media by normal coordinates with an application to diffraction, *J. acoust. Soc. Amer.* **29,** 3, 381–391, Mar. 1957.

In this important paper, authors develop a new method for investigating stress wave propagation in infinite or almost infinite media. The method is basically an extension of a Lagrangian technique which is fairly common in mechanics and mathematical physics: the use of normal modes as generalized coordinates. In the present paper, the procedure consists in solving the problem first for a finite system and then finding the limiting form of the solution when all (or almost all) the boundaries are expanded to infinity. At first sight, the method appears to be rather esoteric and even artificial, but this misconception is soon removed by the authors who show how the method can be used to solve two specific problems: an idealized, infinitely-rapid explosion in an infinite fluid, and the diffraction of a spherical pulse by an infinite plane wedge or corner. The power of the method becomes evident in the second problem and it leads easily to the explicit solution in closed form, involving only elementary functions.

In the concluding section, authors examine the advantages of their method, comparing it with the more usual methods of Green's functions and linear operators. Authors emphasize that this paper is a preliminary one; it is to be hoped that it is the first of a long series of papers. R. M. Davies, Wales

3839. Ribner, H. S., Boundary-layer-induced noise in the interior of aircraft, *Univ. Toronto Inst. Aerophys. Rep.* 37, 24 pp. + 12 figs., Apr. 1956.

Author treats noise in aircraft interior due to vibration of skin panels excited by fluctuating pressures (psuedo-sound) in the boundary layer. Problem is approached by analyzing the magnitude and acoustic effects of running ripples in the skin. Supersonically moving ripples radiate strong sound; subsonically moving ripples radiate no sound if the sheet is infinite, but multiple reflections at frames or stringers promote standing waves which do produce noise. Provisional calculations of noise levels are made for thin and thick boundary layers.

Reviewer notes that no account is taken of the effect of the external flow on the damping characteristics of the panel. Since the panel damping is of primary importance in determining the sound level, the effects of the external aerodynamic motion-caused forces could well be quite important. J. M. Hedgepeth, USA

3840. Trilling, L., On thermally induced sound fields, *J. acoust. Soc. Amer.* **27,** 3, 425–431, May 1955.

When the temperature of a boundary is varied, the temperature of the gas in the neighborhood of the boundary is changed (by conduction). This induces a local expansion (or contraction) of the volume of gas in the neighborhood of the boundary, producing pressure waves which propagate into the surrounding medium. An excellent analysis of one such case is given in this paper. In the case considered, the temperature of the closed end of a semi-infinite tube is raised suddenly. The thermally induced sound field is calculated and discussed in some detail. The effects of side wall on the thermally induced sound field are also examined.

B.-T. Chu, USA

3841. Shields, F. D., Thermal relaxation in carbon dioxide as a function of temperature, *J. acoust. Soc. Amer.* **29,** 4, 450–454, Apr. 1957.

Much of this paper is a summary of previous theoretical and experimental work on thermal relaxation in gases. Some new measurements on carbon dioxide by conventional acoustical methods are presented as functions of temperature over the range 0 to 200 C. No evidence for two relaxation times was found. The collision efficiency for energy transition between modes is found to vary as $\exp(T^{-1/3})$. F. G. Blake, USA

3842. Parker, J. G., Reflection of plane sound waves from a sinusoidal surface, *J. acoust. Soc. Amer.* **29,** 3, 377–380, Mar. 1957.

In a previous paper [title source **28,** 4,672–680, 1956], author treated title problem by deriving an approximate nonlinear differential equation of the first order (essentially an eikonal equation), neglecting the quadratic terms in it and solving this linear equation.

In order to account for discrepancies between the theory and experimental results [AMR **9,** Rev. 2758], author finds numerically in the present paper a solution of the nonlinear equation (which, however, is still an approximation) for the special case of normal incidence. This solution is in good agreement with the measurements for one value of the ratio amplitude over wave length of the waves of the reflecting surface, while there is a constant deviation for another value of this ratio. Author suggests that this might be due to a systematic error in the measurements.

H. L. Oestreicher, USA

3843. Westervelt, P. J., Scattering of sound by sound, *J. acoust. Soc. Amer.* **29,** 2, 199–203, Feb. 1957.

Taking into account quadratic terms in the nonlinear equations of motion in perfect fluids, author proves that no scattered waves exist outside the region of interaction if two sound beams intersect each other at right angles. F. Borgnis, USA

3844. Andreev, N. N., Some second-order quantities in acoustics (in Russian), *Akust. Zh.* **1,** 1, 3–11, 1955; *Ref. Zh. Mekh.* 1956, Rev. 3456.

The density and flow of acoustic energy, momentum and pressure of acoustic radiation is examined by a method of successive approximation extending to second-order terms.

It is demonstrated that the usual expressions for the flow and density of acoustic energy, as well as their generally accepted mean values, are incorrect; correct expressions for these quantities are derived and their relationship to the accepted formulas determined.

The results are illustrated on the particular example of a unidimensional travelling wave.

The article is a further development of the author's ideas first published in *J. Phys. USSR* **2,** 4,305–312, 1940, incorporating the most recent publications. V. V. Eremin, USSR

Courtesy Referativnyi Zhurnal

Translation, courtesy Ministry of Supply, England

3845. Cook, R. K., Variation of elastic constants and static strains with hydrostatic pressure: A method for calculation from ultrasonic measurements, *J. acoust. Soc. Amer.* **29,** 4, 445–449, Apr. 1957.

The elastic constants and static strains of a solid subjected to large hydrostatic pressures can be deduced from measurements of resonant frequencies (or transit times) for ultrasonic waves in specimens of suitable crystallographic orientations. The pressure changes the specimen's size, shape, and density as well as the elastic constants, and all of the effects influence the resonant frequencies. An algorism for separating out the effects due to variations in elastic constants from the effects due to static strains is presented and applied to cubic crystals and hexagonal crystals. The results apply also to isotropic and transversely isotropic solids. From author's summary by A. H. Hausrath, USA

Ballistics, Detonics (Explosions)

(See also Revs. 3537, 3701, 3786, 3804)

3846. Hancock, M., The aiming problem in aerial gunnery, *Aero. Quart.* **8,** 1, 31-48, Feb. 1957.

Problem has been analyzed previously by approximate (but usually adequate) methods, including linear additions of independent partial solutions. Author solves general problem, taking into account simultaneously general flight paths, both for gun and for target, and important projectile forces, both gravitational and aerodynamic. Combining results of analyses of kinematic and of ballistic aspects, a set of (complicated) equations is obtained permitting design of a gun-sighting system having automatically controlled direction of gun linked through a computer to manually controlled line of sight. Due to its complexity, use of this more general solution probably will be justified only in special applications requiring extreme accuracy. E. L. Knuth, USA

3847. Wast, C. D., Boost phase trajectory analysis techniques, *Jet Propulsion* **27,** 5, 527-533, May 1957.

Analysis of the boost-phase performance of a rocket-boosted missile generally requires the solution of a set of differential equations with variable coefficients. Analytical methods are difficult and time consuming, if not impossible. This paper discusses four numerical approaches to the solution of the equations for a cruciform, uncontrolled missile booster. The first of these, called the "exact" method, will yield results which are as accurate as one cares to make them. The second, referred to as the "semiexact," assumes that deviations from the flight path are small and oscillatory. With this assumption the solution may be completed in two parts: (a) Computation of the speed-time history and (b) substitution of the speed into the remaining equations. The accuracy for short time oblique launch or for long time vertical launch is as good as the "exact." The third, applicable under the same conditions as the "semi-exact" and referred to as "linear speed-time history," assumes a constant acceleration from launch to the end of boost. The accuracy of this method is very good (on the order of 2% for the terminal speed) provided the thrust-time diagram is nearly trapezoidal. The fourth, called "iterative solution for separation speed," yields an approximate value for the terminal speed with accuracy on the order of 2-4%.

The various uses of the different methods are also discussed as well as techniques for including cross winds, estimating separation speeds and tolerances allowed in estimation of step-wise acceleration. Sample calculations for the three approximate methods are given. From author's summary

3848. Casci, C., The possibilities of a missile in vertical flight (in Italian), *Aerotecnica* **36,** 1, 27-36, Feb. 1956.

The design of rocket-propelled missiles involves a number of considerations about several variables. It is, of course, impossible to take all such variables into account.

In another paper, author discussed these parameters and showed how it is possible, through successive integrations, to determine the highest altitude reached by a missile in its vertically climbing motion. Author draws a pencil of trajectories for which he makes the following assumptions: $W = 2300$ m/secs and $\phi = 0.02$ $\frac{\text{m secs}}{\text{kg}}$. The "parameter of consumption" and "mass ratio" are assumed as variable parameters. The highest altitudes can be attained only with missiles having a high mass ratio; it is necessary, therefore, to give the utmost importance in the design to the mass ratio making the structures as light as possible; and as missiles of larger sizes are specifically lighter it is only by means of these that the highest altitudes can be attained.

For construction limitations, however, the mass ratio can hardly go over 0.75 in the near future. Finally, as the optimum of the parameters of consumption ranges between 60-70, the combustion time of propellants and, therefore, flight with the rocket in operation, must more conveniently be: (60-70).

The diagrams of figs. 3, 4, 5, 6, and 7 are useful to determine the time the missile takes to reach a certain altitude and the relative velocity and how a certain altitude can be attained with different times, different velocity and, naturally, with types of missiles having different mass ratio and parameters of consumption, and finally, different times of combustion.

Once having fixed the types of propellants to be employed and, therefore, the exhaust velocity and the parameter of fineness, the missiles can be designed in the manner which best answers the purpose of its operation. From author's summary

3849. Glassman, I., Impulse expressions for rocket systems containing a solid phase, *Jet Propulsion* **27,** 5, 542-543, May 1957.

Many procedures have been used for calculating the specific impulse of rocket motors whose combustion products contain solids. Since for the pure gaseous system the expression

$$I_{sp} = \sqrt{\frac{2}{g}\frac{\gamma}{\gamma - 1}\frac{R}{M.W.}T_c\left[1 - \left(\frac{p_c}{p_c}\right)^{\gamma/(\gamma - 1)}\right]}$$

has seen general use, this note attempts to show that the specific impulse of a gas-solid system can be represented by similar expressions in which the ratio of the specific heats and the average molecular weight are redefined.

From author's summary

3850. Leitmann, G., Stationary trajectories for a high-altitude rocket with drop-away booster, *Astronaut. Acta* **2,** 3, 119-124, 1956.

A solution to the problem of optimum thrust programming is deduced for a rocket which is required to reach given altitude with given pay load (rather than given burnt mass) and minimum fuel expenditure; i.e., the effect of rocket dead-weight is taken into account. In particular, the case of a rocket with disposable booster is considered, and the necessary conditions for a minimum initial mass are found. From author's summary

Soil Mechanics, Seepage

(See also Revs. 3864, 3866)

3851. Freudenthal, A. M., and Lorsch, H. G., The infinite elastic beam on a linear viscoelastic foundation, *Proc. Amer. Soc. civ. Engrs.* **83,** EM 1 (*J. Engng. Mech. Div.*), 22 pp., Jan. 1957.

Foundation soil is approximated by a series of viscoelastic independent elements uniformly spaced under the beam. Viscous motion is assumed to obey Newton's linear law.

Maxwell mechanical model in which elastic spring and viscous dashpot are arranged in series represents creep or relaxation and approximates short-time behavior of soil, due to shear.

Kelvin model (spring and dashpot in parallel: after-effect) approximates long-time consolidation of soil under permanent load.

Other models represent compound conditions.

Authors derive for each model the equation relating deflection y (at time t) to given force $q(t)$.

In the differential equation of the elastic beam, involving deflection y, soil pressure q, and given load p, by substitution of the model relation the unknown functions are reduced to one (y or q).

Integrals of this equation are thus derived for different load conditions; finally, shear forces and bending moment distributions in the beam are analyzed, as functions of time t.

Fourier series are employed for a space-periodic indefinite load, Fourier integrals for a partial, uniformly distributed, or a concentrated load on infinite beam. Numerical example is worked out for elastic beam loaded by equally spaced columns (space-periodic load). On a Kelvin (after effect) foundation the initial condition is the one of rigid soil ($y = 0$, $q = p$), the final condition corresponds to perfectly elastic soil.

In the case of a relaxing Maxwell foundation the beam lies initially on a perfectly elastic soil and finally behaves as a floating beam, since pressure q becomes uniform, gradually spreading far from the column while deflections y steadily increase. Positive and negative bending moments shall sensibly surpass the moments calculated for a beam on elastic foundation; therefore authors remark that the assumption of elastic soil may be unsafe, if irrecoverable shear deformations are significaut.

D. Gentiloni-Silverj, Italy

3852. Steyer, K. H., Computation of foundations with allowance of the elastic deformations of the foundation and the underlying layers (in German), *Bautechnik* **33,** 12, 423–426, Dec. 1956.

Paper contains a contribution to the determination of contact pressures between the elastic foundation and the underlying layers under the assumption that the dependence of deflection and force acting on the layer is linear. Formulas, given without derivation, describe some simple cases of loadings. Complicated cases can be solved by means of superposition. Finally, approximate method for computation of rigid foundations is introduced; however, in reviewer's opinion, without satisfactory explanation of accepted assumptions. V. Kopriva, Czechoslovakia

3853. Sokolovskii, V. V., On the stability of foundation beds of laminated cohesionless material (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **22,** 74–82, 1955.

Paper is devoted to solution of a plane stress problem involving a bed of laminated cohesionless granular material of such a nature that it has two different values of the angle of friction, a smaller value related to the horizontal planes and a larger value on all other planes. A limiting state of equilibrium, with the material on the verge of sliding at all points, is assumed throughout the whole mass. Author distinguishes two kinds of regions: the regions of ordinary limiting equilibrium, where the sliding is impending on the inclined planes, and the special regions, where the sliding is due to occur on the horizontal planes. The former regions are subject to the usual differential equations of limiting equilibrium, while different differential equations hold in the latter regions. Author applies this general theroy to a semi-infinite mass of soil with a horizontal free surface, one half of which is free of any external loads. The soil region is found to consist of three zones of ordinary equilibrium and a zone of special equilibrium. The boundaries of different zones are found, as well as the stresses in them, and the manner of loading of the second half of the free surface is also determined. A set of graphs and figures illustrate the application of the theory to some particular numerical cases.

A. Hrennikoff, Canada

3854. Babkov, V. F., The resistance of soils to deformation at different rates (in Russian), *Trudi Mosk. avtomob.-dor. in-ta* no. 16, 107–119, 1955; *Ref. Zh. Mekh.* 1956, Rev. 4705.

The well-known phenomenon is described of the change in deformation resistance of elastically viscous plastic media with the rate of deformation. Author has constructed an apparatus for the demonstration of the correctness of his hypothesis that the resistance of soils to deformation can be most simply defined by two rectilinear segments instead of the customary logarithmic curve. In this regard, author assumes that the change in the rate of penetration does not alter the character of the relationship between the penetration resistance and the depth of penetration of the ram. The experimental speeds were varied between 0.3 and 380 mm/sec. The experimental results obtained generally confirm the theoretical assumptions of the author for deformation speeds of the order of 1.2 cm/sec and above, but, on the contrary, showed considerable divergence at speeds of the order of 0.03 cm/sec. At deformation rates of the order of 60–80 cm/sec, the resistance of soils to penetration may be considered as independent of the rate. N. N. Ivanov, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

3855. Building Research Advisory Board, A study of the anchorage of exterior frame walls to various types of foundations, *Building Res. Inst. Publ.* no. 446, 1-69, Mar. 1956.

On behalf of the Federal Housing Administration, this study was made by a group of specialists who evaluated existing information and advanced recommendations for design procedures and practices to be instituted by FHA.

The general conclusion was to the effect that all framed structures be anchored to their foundations, except when it is shown that such anchorage is not necessary because of the internal resistance of the structure to both uplift and lateral movement.

Two methods are presented for determining any necessity of anchorage in the light of the wind pressure involved at a particular location. The rapid computation method indicates whether the more exact method of analysis should be carried out.

Report presents nomographs which make it possible to estimate the stability of a house of given height, roof slope, weight per foot of length, and wind pressure to which it is exposed. The forces required to overturn the house and to slide it off its foundation can be readily determined. These two forces have to be resisted by the structure under any conditions, whether or not it is anchored to its foundation. E. G. Stern, USA

3856. L'Herminier, M. R., Study of foundations (in French), *Ann. Inst. tech. Bat. Trav. publics* no. 109, 93–102, Jan. 1957.

An examination is made first of the rupture resistance of a semi-infinite homogeneous layer either cohesionless or coherent with or without internal firction. There follows an examination of the bearing value of a two-layer system. Finally, after studying the limit bearing value of these layers, there is an examination of the distribution of pressures under a shallow footing, loading the soil, not to the point of rupture but to an admissable working load.

From author's summary

3857. McClelland, B., and Focht, J. A., Jr., Soil modulus for laterally loaded piles, *Proc. Amer. Soc. civ. Engrs.* **82,** SM 4 (*J. Soil Mech. Found. Div.*), Pap. 1081, 22 pp., Oct. 1956.

Using results from a lateral load test on a 24-in. pipe pile and laboratory tests on undisturbed clay samples, a tentative procedure for estimating the soil modulus of pile reaction is developed for problems involving transient loads. The correlation derived is based on the similitude on logarithmic paper of laboratory stress-strain curves and soil reaction-deflection curves from the pile test.

From authors' summary

3858. Budagovsky, A. I. M., The permeation of water into the soil (in Russian), *Moscow, Akad. Nauk SSSR*, 137 pp. + illus. 1955; *Ref. Zh. Mekh.* 1956, Rev. 4594.

A brief analysis is made of the permeation of water into the soil, based on the results of laboratory and field tests made by author and other research workers. The relationship between intensity of permeation, and the humidity and temperature of the soil is examined. It is found that the intial degree of humidity very materially influences the intensity of permeation, particularly in heavy soils; with increasing initial wetting of the soil, the intensity of permeation decreases, as well as the coefficient of filtration. With decreasing temperature, the viscosity of the water changes, causing a further decrease in the coefficient of filtration. The influence of change in the surface tension of the water is in this case, however, insignificant.

Consideration is given separately to the influence of inhomogeneity of the soil on free and pressure infiltration. In the upper stratum of the soil, the value of the coefficient of filtration is governed by the intensity of the rainfall. Farther down, free infiltration is replaced by pressure infiltration. In the latter case, the intensity of permeation is determined, as in the case of a homogeneously deposited soil, by the Darcy equation, the only difference being that the relevant parameters become variable, depending on the location of the permeation front. The last chapter discusses briefly the methods of making field tests and calculations of the water permeation of a soil. Author recommends investigation of the water permeability of a soil by layers, which permits determination of the filtration coefficient and the other values necessary for drawing the permeation curve for infiltration under pressure.

It is noticeable that no recent foreign work on this subject is referred to. A. R. Shkirich, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

Micromeritics

(See also Revs. 3674, 3801, 3813, 3829, 3858)

3859. Pilcher, J. M., Mitchell, R. I., and Thomas, R. E., The cascade impactor for particle-size analysis of aerosols, Proc. Ann. Meet., Chem. Specialties Manufacturers Assn., Inc., New York, Dec. 1955. 6 pp. + 9 figs. + 4 refs.

An aerosol is a dispersion in air of solid or liquid particles ranging in size from about 0.1 to 20 microns. The behavior of aerosols depends on the size distribution of the droplets. Particle size largely determines the rate at which the concentration of the aerosol decreases as a result of settling. The importance of gravity, thermal forces, acoustical forces, and Brownian motion depends on the size of the particles involved. Droplet size also influences the penetration distance and the covering power of paint and plastic sprays, retention of medicinal sprays in the respiratory tract. For all these reasons it is important that the particle-size distribution should be capable of being measured.

This is the purpose of the Cascade Impactor, which classifies the particles of an aerosol into various size fractions by impaction on successive slides. It is based on the same principle as that of the pioneer instrument developed by K. R. May, i.e., that a particle in a moving aerosol will impact on a slide placed in its path provided the inertia of the particles is sufficiently large compared with the drag force exerted on the particle by the air. Circular jets of successively diminishing diameter are arranged in tandem fashion forming a cylindrical drum, one end of which (near to the smallest diam jet) to a suction pump. Adjacent to the exit side of the jets, slides can be mounted, on which the samples of uniform size drops having successively decreasing diameters can be collected.

Calibration is made by sampling aerosols composed of uniform size droplets. The droplets are counted on the slide, and the slides are weighed on a microbalance before and after the sample is taken; in this manner the histogram of the aerosol is determined. With increasing industrial, agricultural, and other applications of aerosols, an increased use of the Cascade Impactor is predicted.

K. J. DeJuhasz, Germany

3860. Lenz, F., Determination of the size distribution of spherical particles embedded within a solid medium by means of the circular cuts obtained by taking a plane section through the solid medium (in German), *Optik* **11,** 524–527, 1954.

If in a medium there are embedded small spheres of another material, then, by taking a plane section through the medium, the spheres are also sectioned and will present circular shapes in the section. Author investigates the problem of determining, from the distribution of circles in the plane section, the volumetric distribution of the embedded spheres within the medium. This problem is of interest for the microscopic and electron-microscopic examination of sectioned biological and metallurgical specimens, whenever the investigator desires to determine the volumetric distribution of heterogeneous components enclosed within a basic substance from the plane microscopic image. It is also of significance for sprays, for the determination of the three-dimensional distribution of droplets from a picture of droplet distribution taken in one plane.

Mathematically speaking, if $g(r)dr$ is the number of circles in unit area of the section the diameters of which are within r and $r + dr$, and if $f(R)dR$ is the number of spheres within unit volume the diameters of which are within R and $R + dR$, then the problem is to define $f(R)$, i.e., the frequency spectrum of sphere sizes, from the (known) frequency spectrum $g(r)$ of circle sizes. Author derives this relationship, in which the first derivative of the function $g(r)$ enters, which is more sensitive to error than the function itself, i.e., $g(r)$. Therefore, author emphasizes the necessity for first fairing the experimentally obtained $g(r)$ function before deriving from it the sought $f(R)$ function.

K. J. DeJuhasz, Germany

3861. Wu, T. H., Relative density and shear strength of sands, *Proc. Amer. Soc. civ. Engrs.* **83,** SM 1 (*J. Soil Mech. Found. Div.*), Pap. 1161, 23 pp., Jan. 1957.

This investigation consists of a study of the relative density of natural sand deposits and its relationship to the particle size and the shear strength of the soil. An attempt was also made to evaluate the effectiveness of the penetration test as a means of determining the relative density.

Data obtained from four sites show that the relative density of undisturbed specimens is very uniform within an individual stratum, but varies abruptly from one stratum to another. Furthermore, a definite relationship exists between the relative density and the mean particle size of the soil; the greater the mean diameter, the lower the relative density. This phenomenon may be partly explained by the results of a series of consolidation tests. It was found that the compressibility of the soil decreases with increasing mean diameter. Results of triaxial compression tests demonstrate that, within the range of particle size considered, the shear strength, as measured by the angle of internal friction, ϕ is a function of the relative density only. The standard penetration test can be used to estimate the relative density of fine to medium sands. It is, however, not reliable in soils whose largest particle size is 10 mm or greater. From author's summary

3862. Ringqvist, G., Method for determination of specific surfaces applied to coarse-grained powders, *Proc. Swedish Cem. Concr. Res. Inst., Roy. Inst. Technol., Stockholm* **28,** 1–28, 1955.

By measuring the work done during the withdrawal of liquid from the capillaries in a bed of powdered material saturated with liquid, the external specific surface of the material under test can be determined with an accuracy which is higher than that corresponding

to an error of 10% in a range extending from 25 $cm^2 \cdot g^{-1}$ to 3000 $cm^2 \cdot g^{-1}$.

This method has also been used for measuring specific surfaces of up to 10,000 $cm^2 \cdot g^{-1}$, but the accuracy was then found to be slightly lower.

The equipment required for the tests made by means of author's method is extremely simple and easy to handle. The results of measurements are independent of the particle shape, the particle size distribution, and the density of the material to be tested. They are likewise independent of the degree of compaction of the powder bed. The effect of the test temperature on the results of measurements amounts to about 2% per degree centigrade.

The results of measurements are evaluated by the aid of a simple, empirical formula containing two constants, which are dependent on the liquid used in the tests and on the test temperature. These constants can be determined once for all by means of calibration tests on standard samples whose specific surfaces are known.

From author's summary

3863. Slezkin, N. A., and Shustov, S. N., The steady motion of a suspended particle in a laminar flow (in Russian), *Dokladi Akad. Nauk SSSR* (N. S.) **96,** 5, 933–936, 1954; *Ref. Zh. Mekh.* 1956, Rev. 4398.

Authors investigate title problem by means of a hypothetical formula advanced by them defining the lateral forces exerted on a particle by vortices in a laminar flow. F. I. Frankl', USSR

Courtesy Referativnyi Zhurnal

Translation, courtesy Ministry of Supply, England

3864. Charny, I. A., The calculation of the percolation interval in a no-pressure feed to incomplete and complete boreholes (in Russian), *Trudi Mosk. neft. in-ta* no. 14, 242–250, 1955; *Ref. Zh. Mekh.* 1956, Rev. 4582.

An attempt is made at developing an approximate method of calculating the inflow of gassy petroleum to a bore, with consideration of the associated water and the volume density of the petroleum. The known differential relationship between the weighted mean pressure and the weighted mean petroleum saturation, as well as empirical relationships for the gas and petroleum permeabilities are used to derive an approximate formula for the determination of the weighted mean pressure from the weighted mean petroleum saturation. The relationships obtained are presented graphically. Some conclusions are drawn concerning the influence of the saturation of the associated water with the petroleum yield of the stratum.

Courtesy Referativnyi Zhurnal S. N. Numerov, USSR

Translation, courtesy Ministry of Supply, England

3865. Zheltov, Yu. P., and Kristianovich, S. A., Hydraulic fracturing of petroleum-bearing strata (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 5, 3–41, May 1955.

This comprehensive paper covers: (a) rock load, (b) horizontal fracture, (c) vertical fracture, (d) wedge effect, in an attempt to find critical pressure p^* at which rupture of strata and increased discharge occur. Experimental data are still lacking and authors are left to make assumptions.

(a) Load involves stresses transmitted across soil skeleton and component of fluid pressure. From Lamé's formulas for axisymmetrical plane deformation, expressions are derived for stresses in elastic porous strata under excess pressure Δp_c at well. Analysis is extended to case with a plasticity criteria $r = k$. It is refined by regarding strata as half-space under given strain and normal stress (Galin's solution). Special attention is given to sandstone and clayey strata.

(b) Strata is limited by two impervious layers. On the basis of half-space elastic solution, approximate value is derived for critical excess pressure Δp^* and for width of crack. A relation is indicated between discharge from strata with and without crack. It is derived from data obtained through model study in electrolytic tank. Fracture can extend up to a few ten m.

(c) Cases of back-up fluid with small (permeative), and large viscosity (nonpermeative) are discussed. Vertical fracture appears possible only in a few cases. Rupture depends on product $Q.\eta$. With nonpermeative fluid, critical pressure is much larger than that with permeative at moderate depths. For large depths both are about equal. Work and experiments of Scott-Bearden-Howard [AMR **6,** Rev. 3933] are often referred to.

(d) Authors consider vertical fracture opening under pressure of very viscous fluid (large $Q.\eta$). Pressure distribution along face of crack depends upon its unknown shape. Fluid occupies only portion of length of crack. Simplified problem can be solved by approximations. Basic procedure is to apply Muskhelishvili's method for two-dimensional elastic problems. Assumed symmetrical crack is mapped onto unit circle; it is subjected to given normal stresses. One obtains displacements (i.e. increased width of crack), hence the relative pressure distribution.

Reading of paper is complicated by cumbersome notation. Some obvious considerations could have been left out.

G. H. Beguin, Switzerland

Book—3866. Pavlovskii, N. N., Collection of works (in Russian), Moscow-Leningrad, Academy of Sciences 1956, 771 pp. $5.55.

This volume contains 13 works on ground-water movement, published 1922–1937 in various limited editions and journals: (1) Theory of ground water movement under hydraulic structures and its applications (1922), 1–352. (2) Hydromechanical design of Senkov-type dams (1937), 353–408. (3) Ground-water flow to canals and rivers and percolation forces (1935), 409–414. (4) Hydromechanical solution of a problem on free seepage from open channels (1936), 415–436. (5) Free indefinite seepage from open channels of circular section (1936), 437–471. (6) Application of the Kirchhoff complex to the hydromechanical problem of free seepage (1937), 472–493. (7) Water flow to horizontal filters (1937), 494–512. (8) Nonuniform flow of ground waters (1930), 513–545. (9) Further development (1932), 546–599. (10) Seepage through earth dams on impermeable foundations (1931), 600–734). (11) Hydraulic theory of turbulent motion of ground waters (1934), 735–745. (12) Hydraulics and hydromechanics of ground waters (1932), 746–748. (13) Determination of apron thickness (1923), 749–764.

Several of these works are classical in the field of fluid seepage through porous media. S. Kolupaila, USA

Geophysics, Meteorology, Oceanography

(See also Revs. 3708, 3827)

3867. Greenspan, H. P., The generation of edge waves by moving pressure distributions, *J. fluid Mech.* **1,** 6, 574–592, Dec. 1956.

Edge waves are long period waves of considerable length which are propagated along shore. Their effect is not felt far out at sea. Author attacks the problem of their generation by a pressure disturbance moving parallel to the coast with the disturbance originating at a finite time. Author chooses a straight coast line and the slope of the bottom to be a linear function of distance from the shore. The Munk, Snodgross & Carrier model forms the basis but is extended to a Gaussian pressure distribution. No effect of the earth's rotation is included in the model. Mathematical model used gives rise to an infinite number of modes whose wave lengths, frequencies, and amplitudes appear to agree well with some observations of hurricanes. Apparently the hurricanes excite the fundamental mode only.

A discussion of the effects of storm size, speed, and distance from shore is given. W. P. Elliott, USA

3868. Rao, V. N., An electronic sea-wave recorder, *Trans. Amer. geophys. Un.* **38,** 1, 50–55, Feb. 1957.

Article describes a surface type of sea-wave recorder which is based on the principle of the variation in the capacitance between the sea water and an insulated wire placed vertically in it with changes in the level of the sea water. This change in capacitance is used to modulate the frequency of an oscillator. An electronic unit is used for recovering from the frequency-modulated signal an electrical voltage which is an exact replica of the sea wave. This electronic unit is described in detail. The type of recording suitable for various applications and also the performance characteristics of this instrument are discussed.

From author's summary

3869. Reed, F. V., Behavior of a proposed oceanographic research vessel in waves, *David W. Taylor Mod. Basin Rep.* 1055, 11 pp., Aug. 1956.

A 5-ft model of a proposed oceanographic research vessel was tested for seaworthiness. Measurements of speed, pitch, and heave were made in a variety of wave conditions with the model heading into the waves, and qualitative observations were made in several wave conditions with the model in following seas.

From author's summary

3870. Goody, R. M., The influence of radiative transfer on cellular convection, *J. fluid Mech.* **1,** 4, 424–435, Oct. 1956.

Author approaches the stability and circulation of planetary and stellar atmospheres by analyzing a simple analog, viz., the onset of convection between parallel plates heated from below, with the enclosed fluid absorbing and emitting radiation. A general solution to the equations is not possible, but useful quantitative and qualitative information is obtained by considering the two limiting cases of opaque, and wholly-transparent media. The paper is of interest in both the heat-transfer and meteorology fields.

A. Whillier, S. Africa

3871. Coleman, T. L., Press, H., and Shufflebarger, C. C., Effects of airplane flexibility on wing bending strains in rough air, *NACA TN* 4055, 22 pp., July 1957.

Some results on the effects of wing flexibility on wing bending strains as determined from flight tests of a Boeing B-29 and a Boeing B-47A airplane in rough air are presented. Results from an analytical study of the flexibility effects on the B-29 wing strains are compared with the experimental results. Both the experimental and calculated results are presented as frequency-response functions of the bending strains at various spanwise wing stations to gust disturbances. In addition, some indirect evidence of the effect of spanwise variations in turbulence on the responses of the B-47A airplane is presented.

From authors' summary by J. V. Becker, USA

3872. Hakkinen, R. J., and Richardson, A. S., Jr., Theoretical and experimental investigation of random gust loads. Part I—Aerodynamic transfer function of a simple wing configuration in incompressible flow, *NACA TN* 3878, 64 pp., May 1957.

Measurements of sinusoidally oscillating downwash and lift produced on a simple rigid airfoil have been made. Comparison with theory indicates agreement in order of magnitude and trend, although the scatter of results precludes their use for direct verification of Sears' gust function. Necessary improvements in experimental techniques are discussed.

Measurements of statistically stationary random downwash and corresponding lift on a simple rigid airfoil have been made and values of the transfer function between their power spectra determined. An approximate analysis has been carried out and the results are compared with the present experimental results as well as with those of another investigation. Reasonable agreement is shown at high reduced frequencies. A more extensive measurement program is recommended.

B. E. Gatewood, USA

3873. Richardson, A. S., Jr., Theoretical and experimental investigation of random gust loads. Part II—theoretical formulation of atmospheric gust response problem, *NACA TN* 3879, 50 pp., May 1957.

Equations of motion are derived for the dynamic response of aircraft to random atmospheric gust loads. These equations include the degrees of freedom of plunging, pitching, rolling, and an arbitrary number of elastic normal modes. Solutions of these equations are expressed in terms of a number of so-called primitive solutions obtainable by introducing the Dirac delta function. The solutions for center-of-gravity acceleration response and wing-root bending-moment response depend upon certain autocorrelations and cross correlations which enter the analysis. Results for simplified cases show that unsteady aerodynamic theory is not important for increasingly large values of the turbulence scale compared with values of the wing chord. However, the pitching degree of freedom exhibits an important effect as the turbulence scale increases. The results are also compared with the results of the usual sharp-edged-gust formula.

B. E. Gatewood, USA

3874. Press, H., Meadows, M. T., and Hadlock, I., A re-evaluation of data on atmospheric turbulence and airplane gust loads for application in spectral calculations, *NACA Rep.* 1272, 29 pp., 1956.

It is assumed that atmospheric turbulences are "locally" (geographically and time-wise) Gaussian and stationary, but the gust intensity has a probability distribution pertaining to each transport operation, route, and weather condition. This probability distribution, together with an assumed expression for the reduced power spectral density for atmospheric turbulence, permits the calculation of the conventional gust statistics, which is expressed in terms of the number of gusts or acceleration peaks per second exceeding given values. Paper reviews available data on the power spectrum, and gust statistics for several transport operations, attitudes, weather conditions; it derives the distributions of the gust velocity. A method of applying these results to the calculation of airplane gust-response histories is also outlined.

Reviewer believes that the bold assumptions introduced in this paper have the important merit of simplifying the problem sufficiently to make the spectral analysis a practical tool. Authors have shown considerable experimental evidence in support of these assumptions.

Y. C. Fung, USA

3875. Hay, J. S., and Pasquill, F., Diffusion from a fixed source at a height of a few hundred feet in the atmosphere, *J. fluid Mech.* **2,** 3, 299–310, May 1957.

The results of measurements of the vertical distribution of airborne particles, released usually at a height of 500 ft, and sampled for periods of about 30 minutes at downwind distances of 100, 300, and 500 meters, are presented and discussed.

At all distances the frequency distributions of the particle elevation with respect to the site of release are closely similar in shape and size to the frequency distribution of wind inclination at the site of release. This is interpreted as showing that, despite the uncorrelated effects of small eddies, high correlation was maintained in the motion of a particle, for periods of one minute or more, by the dominant action of persistent eddies which contributed heavily to the turbulent energy. In contrast to this result, the wind observations showed that the Eulerian autocorrelation coefficient (R_t) fell to about 0.2 in 10 seconds.

From authors' summary by K. H. Jehn, USA

3876. Thompson, P. D., A heuristic theory of large-scale turbulence and long-period velocity variations in barotropic flow, *Tellus* **9,** 1, 69-91, Feb. 1957.

"Turbulence" as used in this paper refers to large fluctuations on the scale of cyclonic storms. It has only a formal, mathematical similarity to turbulence encountered in fluid flow by engineers. Using statistical methods which involve autocorrelations of eddy velocities, author develops a system of three differential equations which relate the mean west-east wind, the size of "eddies", and the intensity of the eddies. Theoretically this system of equations could be solved and used to predict the future value of each of these three variables if their initial distribution were specified. By use of simplifying assumptions, author reduces the system of three equations to a single equation involving the behavior of the mean west-east wind only. This he solves by numerical methods for certain specific initial conditions. He shows that a maximum in the averaged west-east wind (the so-called "jet stream") may tend to move north or south of its initial position or to split into two maxima. This splitting of the maximum of the mean he interprets as an actual physical splitting of the jet stream. He fails to point out that, due to his method of averaging along latitude circles, the apparent splitting could just as well be a statistical phenomenon derived from a meandering, as contrasted to a split, jet. The author concludes his abstract: "Since these features of long period velocity fluctuations . . . have a characteristic time scale of a week or two, numerical prediction methods based on the present theory show some promise of aiding in the preparation of extended range forecasts."

F. I. Badgley, USA

3877. Ogura, Y., A supplementary note on the relation between the space- and time-correlation functions in a turbulent flow, *J. meteor. Soc. Japan (2)* **33,** 1, 31-37, Feb. 1955.

The simple mathematical illustration of isotropic turbulence presented by the author in a recent paper [AMR **7,** Rev. 2713] is extended to include the correlation tensor of turbulent velocities and it is shown theoretically how the time-correlation tensor of velocities observed at a fixed point is related to the space-correlation tensor. The results are successfully applied to the diffusion of matter emitted from a fixed point source in a turbulent flow. From author's summary by Neal Tetervin, USA

Lubrication; Bearings; Wear

(See Revs. 3561, 3876)

Books Received for Review

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